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MAPS SHOWING QUATERNARY GEOLOGY OF THE SOUTHERN MARYLAND PART OF THE CHESAPEAKE BAY

By Steven M. Colman and Jeffrey P. Halka

Prepared in cooperation with the
MARYLAND GEOLOGICAL SURVEY

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MISCELLANEOUS FIELD STUDIES MAP
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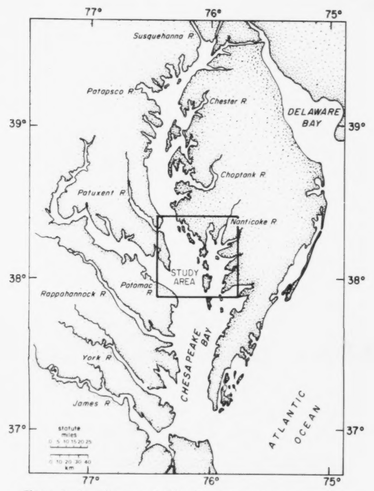


Figure 1.--Location map showing the study area in the southern Maryland part of the Chesapeake Bay.

Table 1.--*Stratigraphic units, southern Maryland part of the Chesapeake Bay*

This report			Mixon (1985)		Time units	
Paleo-channel	Fill unit		Member	Formation		
Cape Charles	Qc	Qc2		Unnamed	Holocene	Quaternary
		Qc1				
Eastville	Qe	Qe2		Kent Island Fm	Pleistocene	
			Occahannock Mbr			
			Butlers Bluff Mbr			
			Stumptown Mbr, Unit B-C	Nassawadox Fm		
		Qe1	Stumptown Mbr, Unit A			
Exmore	Qx	Qx2	Accomack Mbr, Facies B-D	Omar Fm		
		Qx1	Accomack Mbr, Facies A			
Tm				Yorktown Fm Eastover Fm	Pliocene Miocene	Tertiary

INTRODUCTION

The Chesapeake Bay area is a focus of intense concern about environmental issues and natural resources. Although considerable research, including numerous geologic studies, has been done on the bay, much of the geologic work has been concerned with modern processes and much of it has been conducted in relatively small areas. Surprisingly little is known about the geologic history of the main part of the bay, as recorded in the subsurface. This report describes the results of a geophysical survey of the southern Maryland part of the Chesapeake Bay (fig. 1). This survey is a component of a larger effort to study the Quaternary geology and history of the entire main portion of the bay. Similar reports concerning the Virginia part of the bay have been published previously (Colman and Hobbs, 1987, 1988).

About 780 km of high-resolution seismic-reflection profiles were collected in the study area along the tracklines shown in figure 2. The bulk of the geophysical data were collected in September 1985 during a cruise aboard the R/V Discoverer; minor supplemental data were collected in the study area during 1986 and 1987. The primary seismic-reflection data were collected using an ORE Geopulse system operated at 280 joules and triggered every 0.5 s. The Geopulse signals were filtered between 300 and 5,000 Hz and were recorded at a 0.25 s sweep rate. Higher resolution seismic-reflection data were collected concurrently using a Datasonics system operated at 3.5 kHz and triggered every 0.5 s. Penetration of the seismic signals into the deposits was locally hindered by biogenic gas in the sediments.

GEOMORPHOLOGY AND SEA-FLOOR CHARACTERISTICS

The Chesapeake Bay is the largest estuary in the United States and one of the largest estuaries in the world. The bay is about 300 km long and averages about 20 km in width (fig. 1). The study area for this map includes the part of the bay between the Potomac and the Patuxent Rivers, and the main part of Tangier Sound. These water bodies also form the major tributary estuaries that join the Chesapeake within the study area.

As its general appearance (fig. 1) suggests, Chesapeake Bay is commonly described as the drowned valley of the Susquehanna River, formed as sea level rose following the last (Wisconsinan) glaciation (Hack, 1957). The dominant bathymetric features in the study area are a deep, mid-bay channel and a prominent channel in Tangier Sound, both of which have irregular longitudinal profiles (fig. 2). The channel in the main part of the bay is as much as 50 m deep in the northern part of the study area, but shoals towards the south and is generally less than 30 m deep in the southern half of the study area. The Tangier Sound channel attains a maximum depth of 32 m in the study area. The major western-shore tributaries, the Potomac and Patuxent Rivers, also contain deep channels, but these channels shoal to about 10 to 15 m at their mouths where they join the main part of the bay. As will be shown, these channels are largely the partly filled portions of the former fluvial channel system of the Susquehanna River, formed during the low sea level episode related to the last glaciation.

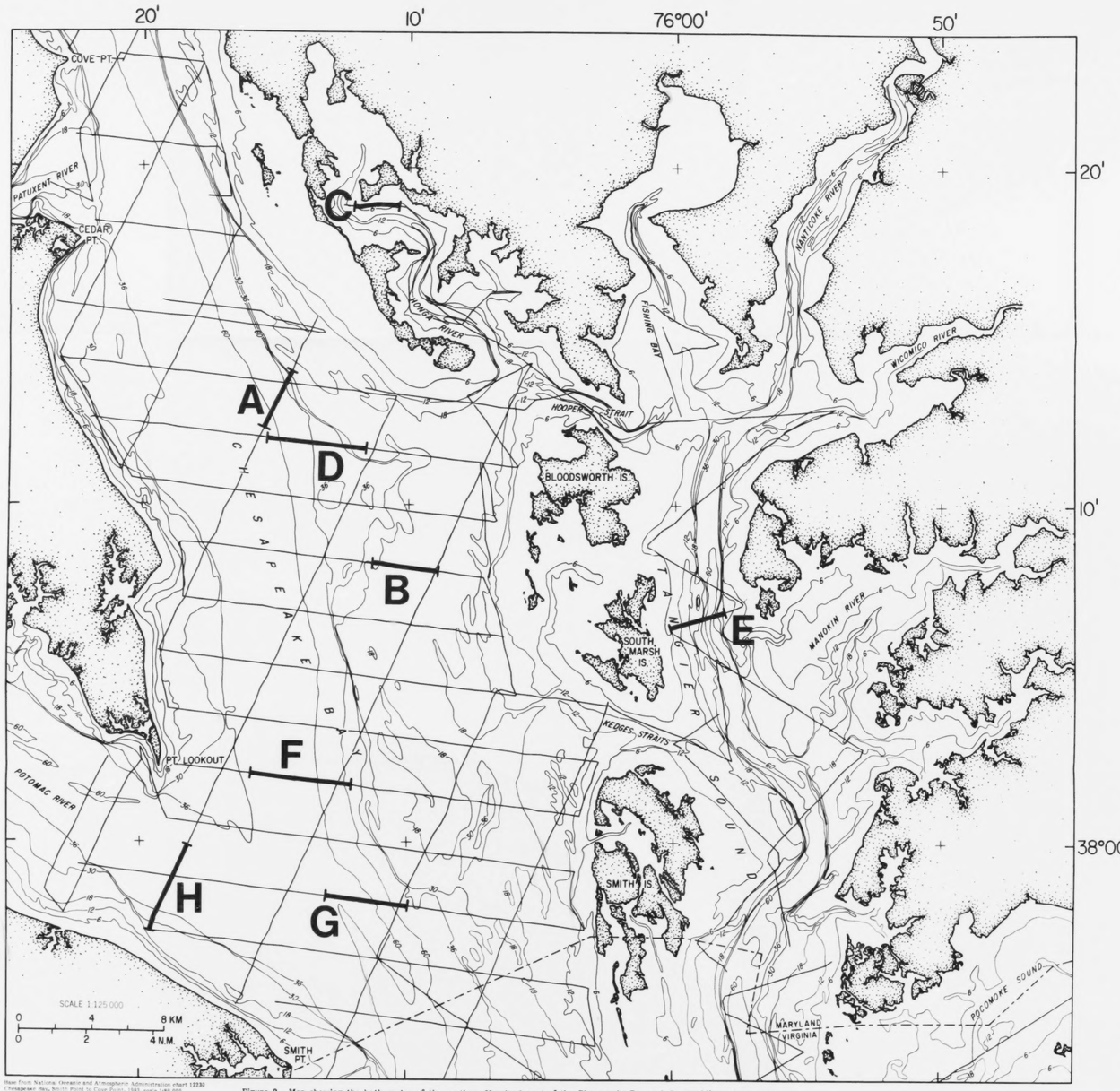
Away from the channels, the bay bottom is relatively shallow and flat (fig. 2). Broad benches that are slightly incised by tributary streams occur along both margins of the bay. The bench on the western side of the bay occurs in water depths of about 10 to 15 m, whereas that on the eastern side of the main bay is somewhat shallower, about 5 to 9 m. The marginal bench on the eastern side of the main bay displays northwest-trending ridges (fig. 2), which also occur on the nearby islands and wetlands, and which thus appear to be unrelated to modern hydrologic processes. A broad, very shallow platform, generally less than 4 m deep, occurs along the eastern shore of the bay, including most of Tangier Sound; the areas around Bloodsworth, South Marsh, and Smith Islands; and the various rivers and embayments along the eastern shore. Large spit-like features such as those near Cedar Point, Point Lookout, and Smith Point occur near the mouths of major tributary rivers on the west side of the bay (fig. 2). Small, shore-parallel ridges and troughs occur along both shores of the main part of the bay.

Bottom sediment texture in the Maryland part of the Chesapeake Bay has been studied in detail by Kerhin and others (1988). Grain size shows only a very general correlation with bathymetry, in that sands occur primarily along the margins of the bay, whereas finer-grained sediments, mostly silty clays, occur on the deeper platforms and in the channels. The change from sandy to muddy sediments is abrupt and only a narrow, limited zone of mixed sediments separates the two. Sandy sediments are the most aerially extensive type in the southern Maryland part of the bay, extending from the shoreline out to depths of about 8 m on the western side of the bay and to about 16 m on the eastern side. Sand is also present in the main bay channel off the mouth of the Potomac River and in local areas of the western-shore beach. Silty clays cover most of the rest of the western-shore bench, although mixed sediment types (sandy clays and sandy, silty clays) occur in patches in waters less than about 16 m deep. The occurrence of sand and mixed sediment types in deep water decrease the general correlation between grain size and water depth in the study area.

Carbonate contents are uniformly low in the Maryland part of the bay, generally less than about 0.3 dry weight percent. Organic carbon and sulfur contents are relatively high (mean values 1.4 and 0.8 percent, respectively), and are strongly and positively correlated with the percent clay content of the sediments (Kerhin and others, 1988).

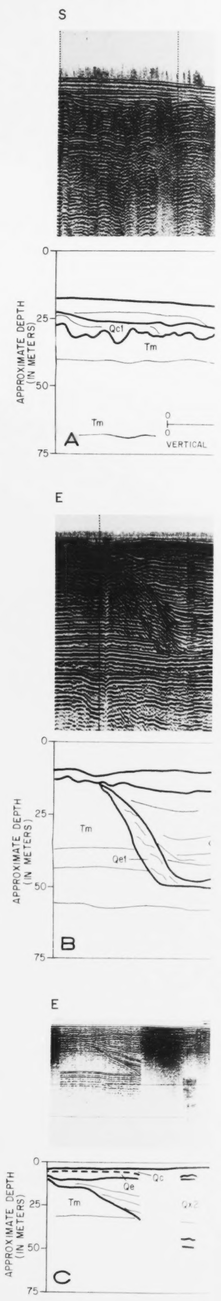
STRATIGRAPHY

The oldest stratigraphic units observed in this study are Tertiary nearshore marine deposits (Tm, figs. 3*A-H*, table 1) that are characterized on the seismic-reflection profiles by strong, continuous, subhorizontal reflections into which irregular Quaternary unconformities are cut.



Base from National Oceanic and Atmospheric Administration chart 12230 (Chesapeake Bay, South Point to Cove Point, 1983, scale 1:80,000
Mercator projection, North American 1927 datum.
Soundings in feet at mean low water.
Not to be used for navigational purposes.

Figure 2.--Map showing the bathymetry of the southern Maryland part of the Chesapeake Bay and the tracklines along which data were collected. Bathymetry from NOAA chart 12230, scale 1:80,000; depth contours at 6, 12, 18, 30, 36, and 60 feet; datum mean low water. Heavy segments of the tracklines with letter labels refer to seismic-reflection profiles in figure 3.



All three paleochannel-fill units, the Exmore (Qx), the Eastville (Qe), and the Cape Charles (Qc), show a similar stratigraphy in both seismic-reflection data (figs. 3*B* and 3*C*; Colman and Hobbs, 1987) and in borehole data (Hack, 1957; Harrison and others, 1965; Meisburger, 1972; Mixon, 1985). The fill of each channel has been divided into two units denoted by suffixes in figure 3. The basal unit (suffix 1) is characterized by short, chaotic, irregular reflections on the seismic profiles, and consists of relatively coarse sand and fine gravel identified in boreholes. The upper unit (suffix 2) is characterized by long, regular, weak to moderate reflections on seismic profiles, and consists of complexly intercalated mud, muddy sand, and peat deposited in estuarine to open-bay environments. Away from the paleochannels, sediments equivalent to the upper units of the paleochannel fills become sandy and are designated by the appropriate unit symbol without a suffix.

The three systems are known to be of distinct ages from cross-cutting relationships (figs. 3*D* and 3*E*) and map patterns beneath the bay, and from stratigraphic relationships on the Delmarva Peninsula (Mixon, 1985). Because the sediments have similar seismic characteristics and because they are poorly preserved on interfluves between the paleochannels, the channels are difficult to distinguish from each other beneath the bay. They can be traced only by using cross-cutting relationships and by projecting their mapped courses. Despite the general similarities in the channel fills, the deposits that fill the Exmore paleochannel show less acoustic contrast and weaker reflections in some cases than do the deposits in the younger paleochannels.

The shallow interfluves and marginal benches generally show only a thin to moderate cover of Holocene sediments, equivalent to the upper part of the fill of the Cape Charles paleochannel. These sediments show weak or no internal reflections (fig. 3*F*). Small tributaries to the Cape Charles paleochannel are apparently filled with thicker Holocene sediments, which almost invariably contain biogenic gas, obscuring the seismic records (fig. 3*F*). Small, flat-lying remnants of older Pleistocene deposits may locally underlie the Holocene sediments on the marginal benches, but such deposits are difficult to distinguish from the underlying Tertiary strata. Most pre-Holocene deposits were apparently eroded from the interfluves and marginal benches during low sea-level stands and were preserved only in the deep paleochannels (Colman and Hobbs, 1987).

DISCUSSION

The reconstructed erosion surface at the base of the Cape Charles paleochannel is clearly of fluvial origin (fig. 4). The isopach map of the sediments, mostly of Holocene age, above this unconformity mirrors the pattern of the erosion surface, showing the close association between preexisting topography and sediment accumulation (fig. 5). In general, the thickest Holocene sediments occur in the paleochannels, whereas only thin sediments occur on the interfluves and marginal benches. Figures 4 to 9 were constructed assuming a sound velocity of 1,500 m/s for water and Holocene sediment, 1,600 m/s for the sediments that fill the Eastville channel system, and 1,800 m/s for the sediments that fill the Exmore

Off Smith Point, this relation suggests that Smith Point has prograded eastward, displacing the modern channel from its original position above the Cape Charles paleochannel (Colman and Hobbs, 1988). Off the mouth of the Potomac River, two bathymetric channels exist, one underlain by the main Cape Charles paleochannel and the present tributary channel of the Potomac River, and the other underlain only by the modern bathymetric channel of the main bay and relatively little channel fill sediments (fig. 3*G*). This relation and the presence of sandy sediments in the channel bottom suggests that the modern bathymetric channel of the main part of the bay has migrated eastward. In addition, Tertiary strata outcrop along the eastern margin of the Cape Charles paleochannel along much of its length between the Patuxent and Potomac Rivers (fig. 3*A*).

The erosion surface that marks the base of the Eastville paleochannel is less extensively preserved than that of the Cape Charles paleochannel (fig. 6), but it is not obscured by gas-charged sediments. Erosion during the formation of the Cape Charles erosion surface removed nearly all of the pre-existing Pleistocene sediment from the interfluves and parts of the Eastville channel system, especially in the northern part of the study area, where the trunk channel of the Cape Charles system directly overlies that of the Eastville system. However, most of the Eastville system can be reconstructed, and the fluvial origin of the erosion surface is clear.

The trunk channel of the Exmore paleochannel system is well preserved, but only a few of the major tributaries can be identified (fig. 7). As is the case for the Eastville system, most of the sediments of Exmore age on the interfluves was removed during subsequent low sea-level stands. The Exmore valley shows little regard for the present configuration of the bay, but instead follows the Honga River and Tangier Sound. Throughout this area and the area to the south (Colman and Hobbs, 1988), the Exmore paleochannel occurs east of the main part of the bay, eventually crossing beneath the Delmarva Peninsula (Mixon, 1985; Colman and Mixon, in press). This pattern suggests that the topographic high formed by Smith, South Marsh, and Bloodsworth Islands and the islands west of the Honga River is older than the Exmore paleochannel. Conversely, the topography to the west must be younger. Part of Bloodsworth Island also must be younger than the Exmore paleochannel, because the channel passes through a gap in the topographic high beneath the island.

Figures 8 and 9 show the depth to Tertiary strata and the total thickness of Quaternary deposits, respectively, in the study area and demonstrate the net effect of Quaternary sea-level cycles. The top of the Tertiary is a composite erosion surface that retains the strong fluvial character resulting from several cycles of channel incision. The thickness of the total Quaternary sedimentary section also shows the effect of preexisting fluvial topography on the deposition and preservation of the sediments.

Reconstructions of the three paleochannel systems are shown in figure 10, in which the channel margins were defined by the 30-meter depth contour to each of the fluvial unconformities (figs. 4, 6, and 7). All three paleochannels continue to the south in the bay, ultimately crossing beneath the southern Delmarva Peninsula (Colman and Hobbs, 1987, 1988). The

intergiacial (Sangamon) transgression (Mixon, 1985), which culminated about 125 ka (Colman and Mixon, in press), although uranium-series age estimates range to as young as 70 ka for the youngest of the transgressive deposits (Mixon and others, 1982; Szabo, 1985). The Cape Charles paleochannel was clearly carved during the last (Wisconsinan) glaciation, about 18 ka, when sea level fell to about -85 m on the Atlantic continental shelf (Dillon and Oldale, 1978). Radiocarbon dates on sediments from the lower part of the channel fill range from about 8 to 15 ka (Harrison and others, 1965; Meisburger, 1972; Colman and Hobbs, 1987). The Cape Charles paleochannel has been only partially filled by the continuing Holocene transgression.

The three paleochannel systems form an age sequence that is progressively older and less related to the current configuration of the bay to the northeast (fig. 10). These trends, which are due to changes in geomorphology that occurred during periods of interglacial high sea level, include (1) filling of the extant paleochannel with estuarine sediments, and (2) southward migration of the bay mouth due to building of barrier-spits and southward progradation of the southern Delmarva Peninsula (Mixon, 1985; Colman and Hobbs, 1987; Colman and Mixon, in press). During the present interglaciation, the axial channel of the bay at its mouth has migrated southwestward by as much as 12 km due to these processes (Colman and Hobbs, 1987). As a result, the incision of each successive paleochannel occurred farther to the southwest.

Of the three major marine transgressions that are recorded in the study area, the history and paleogeography of the Holocene transgression, which is continuing at present, is best known because of the preservation of the underlying Cape Charles fluvial erosion surface (fig. 4). This surface is preserved inside the present bay mouth because transgressive erosion was minimal due to the sheltered conditions that existed in the restricted river estuaries. At the height of the last glaciation, about 18 ka, world-wide sea level was 120±60 m lower than at present (Bloom, 1983a); Dillon and Oldale (1978) have estimated that sea level stood at about -85 m on the mid-Atlantic shelf. At that time, the shoreline was many kilometers east of the present Delmarva Peninsula and an integrated fluvial drainage system occupied the Chesapeake Bay. Deep incision of the channels of this system into the underlying Tertiary and younger deposits occurred. Except where they were preserved in the deep older paleochannels, most Pleistocene deposits on the valley walls and interfluves were removed by erosion. Concurrently, the basal channel-fill deposits, consisting of coarse fluvial sand and gravel, were deposited in the Cape Charles channel bottoms.

As sea level rose following the last glaciation, the fluvial channels began to fill with the relatively fine-grained sediment that comprises the bulk of the channel-fill deposits (Mixon, 1985; Colman and Mixon, in press). The initial part of this filling was probably dominated by fluvial sediment, deposited in response to the rising base level. As the valleys were submerged, creating narrow river estuaries, complex associations of sand, mud, and peat were deposited. Near the bay mouth, these sediments have yielded radiocarbon dates of between about 15 and 8 ka (Harrison and others, 1965; Meisburger, 1972).

The interfluves began to submerge when sea level reached about -20

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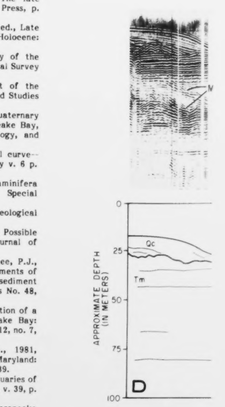

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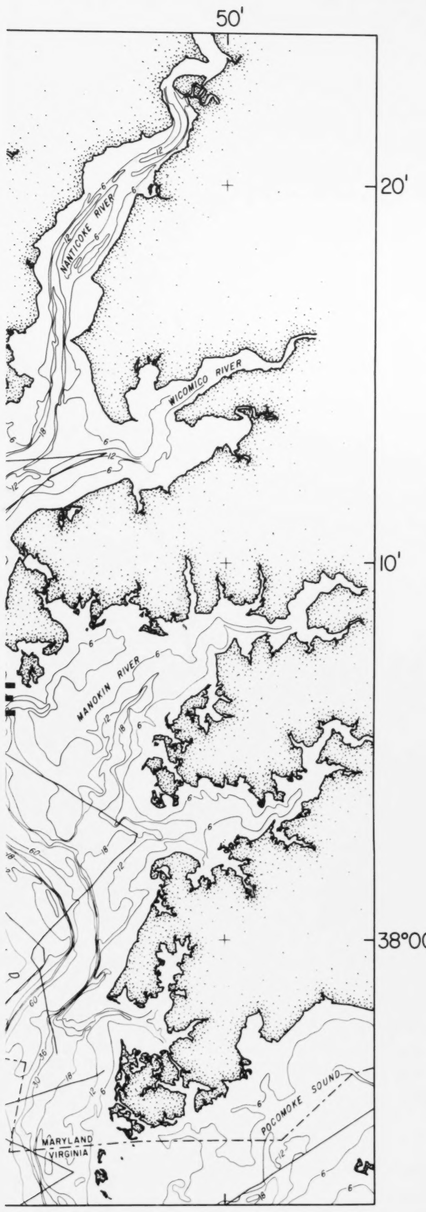

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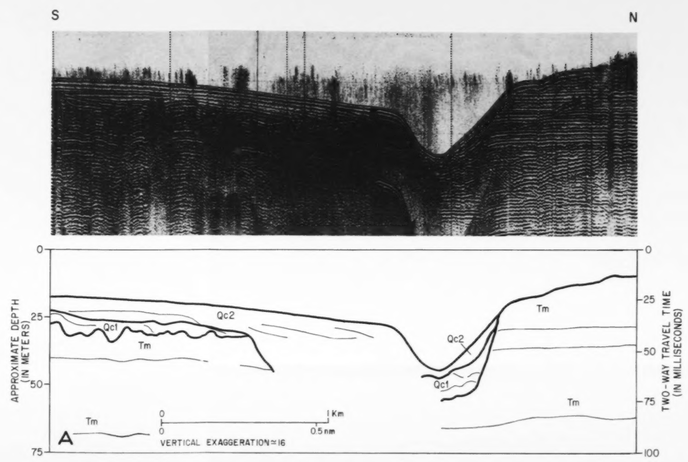

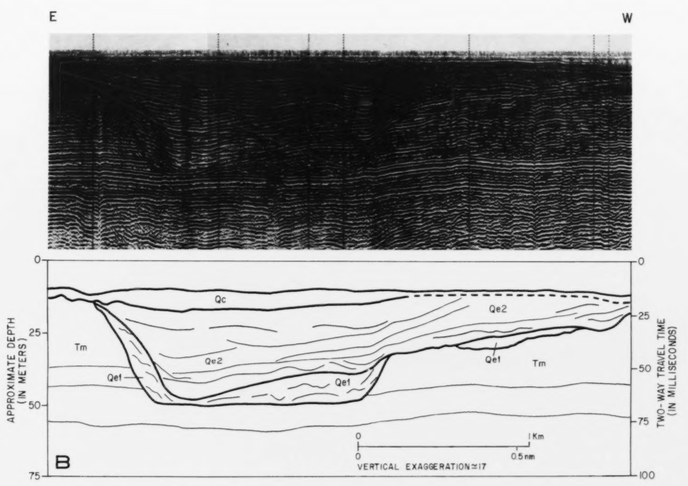

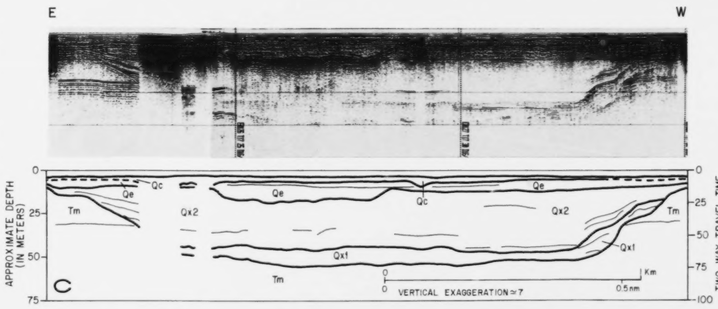

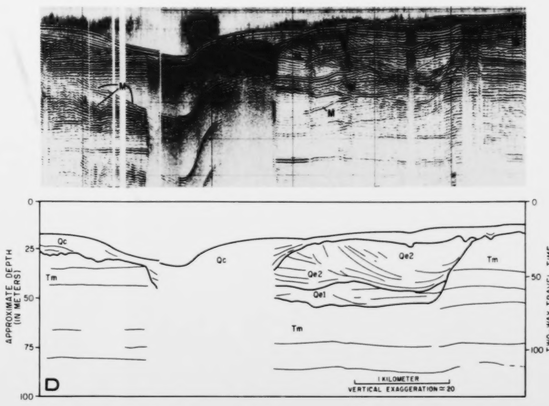

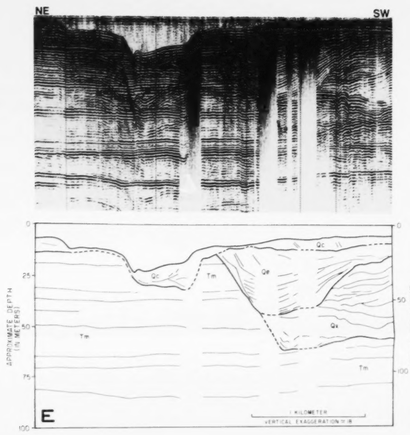

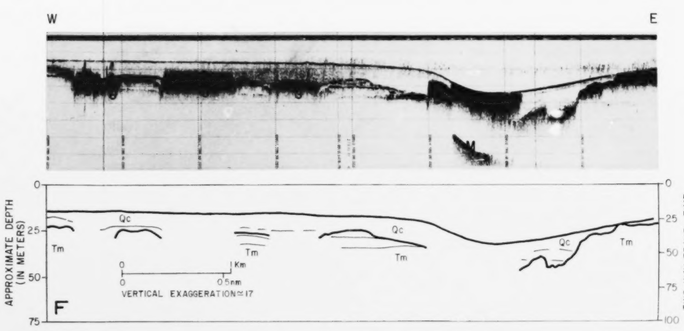

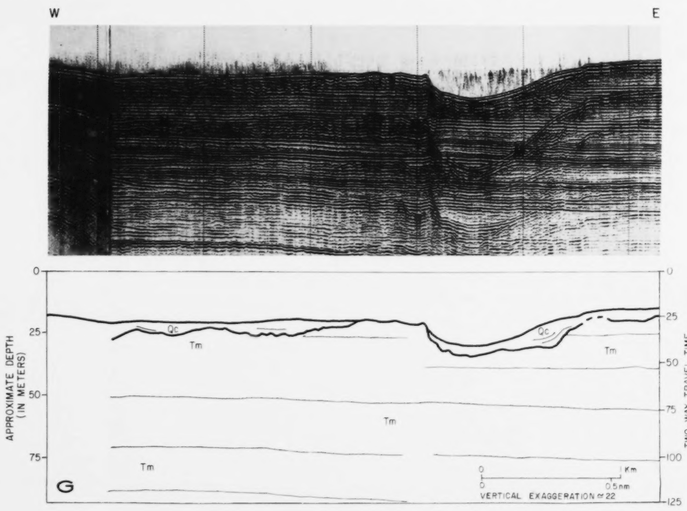

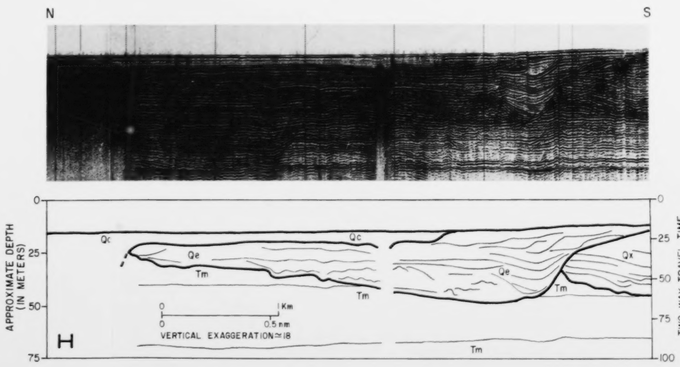

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Figure 3.--Selected seismic-reflection profiles. See figure 2 for locations, table 1 for correlation of stratigraphic units, and the Stratigraphy section in the text for interpretation and description of units. Depth scale on seismic profiles assumes a sound

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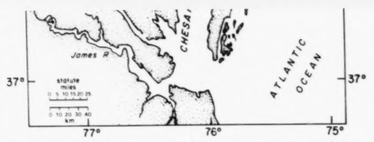


Figure 1.--Location map showing the study area in the southern Maryland part of the Chesapeake Bay.

Table 1.--*Stratigraphic units, southern Maryland part of the Chesapeake Bay*

This report			Mixon (1985)		Time units		
Paleo-channel	Fill unit		Member	Formation			
Cape Charles	Qc	Qc2		Unnamed	Holocene		
		Qc1					
				Kent Island Fm			
Eastville	Qe	Qe2	Occahannock Mbr	Nassawadox Fm	Pleistocene		Quaternary
			Butlers Bluff Mbr				
			Stumptown Mbr, Unit B-C				
		Qe1	Stumptown Mbr, Unit A				
Exmore	Qx	Qx2	Accomack Mbr, Facies B-D	Omar Fm			
		Qx1	Accomack Mbr, Facies A				
Tm				Yorktown Fm	Pliocene		Tertiary
				Eastover Fm	Miocene		

INTRODUCTION

The Chesapeake Bay area is a focus of intense concern about environmental issues and natural resources. Although considerable research, including numerous geologic studies, has been done on the bay, much of the geologic work has been concerned with modern processes and much of it has been conducted in relatively small areas. Surprisingly little is known about the geologic history of the main part of the bay, as recorded in the subsurface. This report describes the results of a geophysical survey of the southern Maryland part of the Chesapeake Bay (fig. 1). This survey is a component of a larger effort to study the Quaternary geology and history of the entire main portion of the bay. Similar reports concerning the Virginia part of the bay have been published previously (Colman and Hobbs, 1987, 1988).

About 780 km of high-resolution seismic-reflection profiles were collected in the study area along the tracklines shown in figure 2. The bulk of the geophysical data were collected in September 1985 during a cruise aboard the *R/V Discovery*; minor supplemental data were collected in the study area during 1986 and 1987. The primary seismic-reflection data were collected using an ORE Geopulse system operated at 280 joules and triggered every 0.5 s. The Geopulse signals were filtered between 300 and 5,000 Hz and were recorded at a 0.25 s sweep rate. Higher resolution seismic-reflection data were collected concurrently using a Datasonics system operated at 3.5 kHz and triggered every 0.5 s. Penetration of the seismic signals into the deposits was locally hindered by biogenic gas in the sediments.

GEOMORPHOLOGY AND SEA-FLOOR CHARACTERISTICS

The Chesapeake Bay is the largest estuary in the United States and one of the largest estuaries in the world. The bay is about 300 km long and averages about 20 km in width (fig. 1). The study area for this map includes the part of the bay between the Potomac and the Patuxent Rivers, and the main part of Tangier Sound. These water bodies also form the major tributary estuaries that join the Chesapeake within the study area.

As its general appearance (fig. 1) suggests, Chesapeake Bay is commonly described as the drowned valley of the Susquehanna River, formed as sea level rose following the last (Wisconsinan) glaciation (Hack, 1957). The dominant bathymetric features in the study area are a deep, mid-bay channel and a prominent channel in Tangier Sound, both of which have irregular longitudinal profiles (fig. 2). The channel in the main part of the bay is as much as 50 m deep in the northern part of the study area, but shoals towards the south and is generally less than 30 m deep in the southern half of the study area. The Tangier Sound channel attains a maximum depth of 32 m in the study area. The major western-shore tributaries, the Potomac and Patuxent Rivers, also contain deep channels, but these channels shoal to about 10 to 13 m at their mouths where they join the main part of the bay. As will be shown, these channels are largely the partly filled portions of the former fluvial channel system of the Susquehanna River, formed during the low sea level episode related to the last glaciation.

Away from the channels, the bay bottom is relatively shallow and flat (fig. 2). Broad benches that are slightly incised by tributary streams occur along both margins of the bay. The bench on the western side of the bay occurs in water depths of about 10 to 15 m, whereas that on the eastern side of the main bay is somewhat shallower, about 5 to 9 m. The marginal bench on the eastern side of the main bay displays northwest-trending ridges (fig. 2), which also occur on the nearby islands and wetlands, and which thus appear to be unrelated to modern hydrologic processes. A broad, very shallow platform, generally less than 4 m deep, occurs along the eastern shore of the bay, including most of Tangier Sound; the areas around Bloodsworth, South Marsh, and Smith Islands; and the various rivers and embayments along the eastern shore. Large spit-like features such as those near Cedar Point, Point Lookout, and Smith Point occur near the mouths of major tributary rivers on the west side of the bay (fig. 2). Small, shore-parallel ridges and troughs occur along both shores of the main part of the bay.

Bottom sediment texture in the Maryland part of the Chesapeake Bay has been studied in detail by Kerhin and others (1988). Grain size shows only a very general correlation with bathymetry, in that sands occur primarily along the margins of the bay, whereas finer-grained sediments, mostly silty clays, occur on the deeper platforms and in the channels. The change from sandy to muddy sediments is abrupt and only a narrow, limited zone of mixed sediments separates the two. Sandy sediments are the most areally extensive type in the southern Maryland part of the bay, extending from the shoreline out to depths of about 8 m on the western side of the bay and to about 16 m on the eastern side. Sands are also present in the main bay channel off the mouth of the Potomac River and in local areas of the western-shore bench. Silty clays cover most of the rest of the western-shore bench, although mixed sediment types (sandy clays and sandy, silty clays) occur in patches in waters less than about 16 m deep. The occurrence of sand and mixed sediment types in deep water decrease the general correlation between grain size and water depth in the study area.

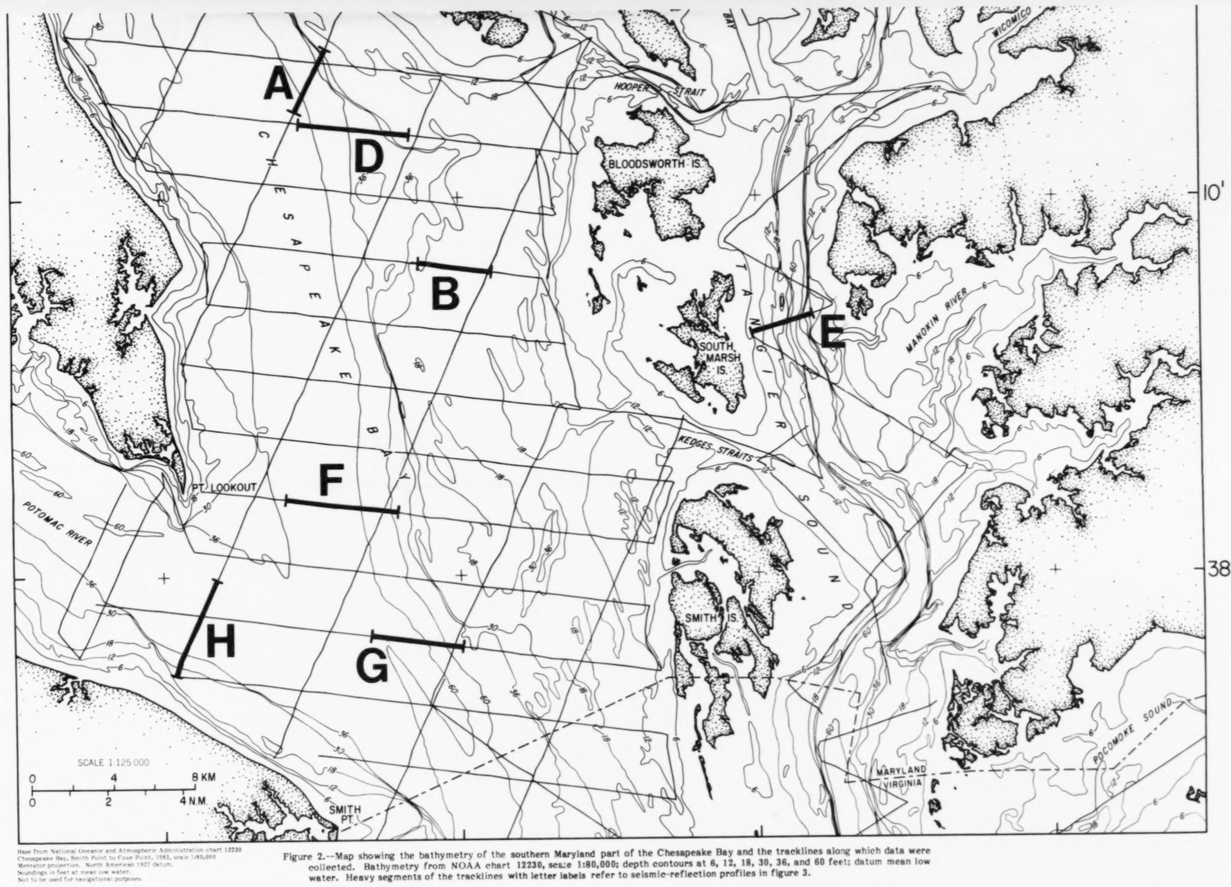
Carbonate contents are uniformly low in the Maryland part of the bay, generally less than about 0.3 dry weight percent. Organic carbon and sulfur contents are relatively high (mean values 1.4 and 0.8 percent, respectively), and are strongly and positively correlated with the percent clay content of the sediments (Kerhin and others, 1988).

STRATIGRAPHY

The oldest stratigraphic units observed in this study are Tertiary nearshore marine deposits (Tm, figs. 3A-*H*, table 1) that are characterized on the seismic-reflection profiles by strong, continuous, subhorizontal reflections into which irregular Quaternary unconformities are cut. Although it is difficult to identify individual Tertiary units on the seismic-reflection profiles away from the land-based wells and exposures where the units have been defined, land-based geologic mapping suggests that the uppermost Tertiary unit in the study area is probably mostly the Eastover Formation of late Miocene age (Ward and Strickland, 1985; Mixon, 1985). The next younger Tertiary unit in the Chesapeake Bay area, the Yorktown Formation of Pliocene age, is largely confined to the area south of the study area (Ward and Strickland, 1985). Limited exposures of Yorktown Formation and younger Pliocene gravels may occur between the Potomac and Patuxent Rivers (Lucy McCarten, U.S. Geological Survey, written commun., 1988), but it is not likely that these upland units are preserved beneath the bay. The St. Marys Formation of middle to late Miocene age underlies the Eastover and crops out above sea level in the Calvert Cliffs, just north of the study area (Vogt and Eshelman, 1987), so that the deeper channels in the study area may cut through the Eastover and into the St. Marys.

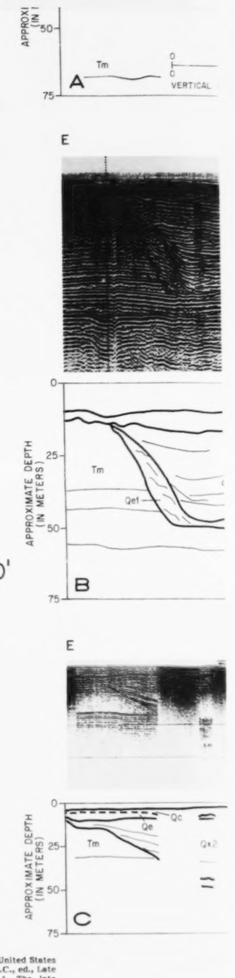
The Quaternary stratigraphy in the study area is dominated by the fill of three distinct paleochannel systems. Each of these systems is associated with a prominent, irregular, basal, erosional unconformity cut into the underlying subhorizontal Tertiary strata. All three paleochannel systems trend seaward beneath the present Delmarva Peninsula south of the study area (Colman and Mixon, in press), and each is informally named for the point at which it crosses the Peninsula. From oldest to youngest, and from north to south on the Delmarva Peninsula, they are the Exmore, Eastville, and Cape Charles paleochannel systems. The trunk channel of the Exmore system in Tangier Sound is equivalent to the Tangier Sound paleochannel reported by Kerhin and others (1980).

The fill of the Cape Charles paleochannel in the study area is almost everywhere obscured on seismic-reflection profiles by biogenic gas in the sediments, which reflects virtually all seismic energy and produces a distinctive signature on the profiles (fig. 3*A*). However, the stratigraphy of the fill is known from seismic-reflection profiles farther south, where the sediments are gas-free, and from borings made for the Chesapeake Bay Bridge-Tunnel (Harrison and others, 1965; Meisburger, 1972; Colman and Hobbs, 1987, 1988) and for the Kent Island Bridge (Hack, 1957). Deposits that fill the older Eastville and Exmore paleochannels contain no biogenic gas, and their seismic characteristics are clear on seismic-reflection profiles (figs. 3*B* and 3*C*). Their stratigraphy is also known from boreholes beneath the Delmarva Peninsula (Mixon, 1985). The fill of the Eastville paleochannel is equivalent to the Stumptown Member of the Nassawadox Formation of Mixon (1985), and the fill of the Exmore paleochannel corresponds to the lower part of the Accomack Member of the Omar Formation (table 1; Mixon, 1985; written commun., 1987).



Base from National Oceanic and Atmospheric Administration chart 12230 Chesapeake Bay, Smith Point to Cove Point, 1983, scale 1:80,000 Mercator projection. North American 1927 datum. Soundings in feet at mean low water. Not to be used for navigational purposes.

Figure 2.--Map showing the bathymetry of the southern Maryland part of the Chesapeake Bay and the tracklines along which data were collected. Bathymetry from NOAA chart 12230, scale 1:80,000; depth contours at 6, 12, 18, 30, 36, and 60 feet; datum mean low water. Heavy segments of the tracklines with letter labels refer to seismic-reflection profiles in figure 3.



All three paleochannel-fill units, the Exmore (Qx), the Eastville (Qe), and the Cape Charles (Qc), show a similar stratigraphy in both seismic-reflection data (figs. 3*B* and 3*C*; Colman and Hobbs, 1987) and in borehole data (Hack, 1957; Harrison and others, 1965; Meisburger, 1972; Mixon, 1985). The fill of each channel has been divided into two units denoted by suffixes in figure 3. The basal unit (suffix 1) is characterized by short, strong, irregular reflections on the seismic profiles, and consists of relatively coarse sand and fine gravel identified in boreholes. The upper unit (suffix 2) is characterized by long, regular, weak to moderate reflections on seismic profiles, and consists of complexly intercalated mud, muddy sand, and peat deposited in estuarine to open-bay environments. Away from the paleochannels, sediments equivalent to the upper units of the paleochannel fills become sandy and are designated by the appropriate unit symbol without a suffix.

The three systems are known to be of distinct ages from cross-cutting relationships (figs. 3*D* and 3*E*) and map patterns beneath the bay, and from stratigraphic relationships on the Delmarva Peninsula (Mixon, 1985). Because the sediments have similar seismic characteristics and because they are poorly preserved on interfluves between the paleochannels, the channels are difficult to distinguish from each other beneath the bay. They can be traced only by using cross-cutting relationships and by projecting their mapped courses. Despite the general similarities in the channel fills, the deposits that fill the Exmore paleochannel show less variability in seismic and weaker reflections in some cases than do the deposits in the younger paleochannels.

The shallow interfluves and marginal benches generally show only a thin to moderate cover of Holocene sediments, equivalent to the upper part of the fill of the Cape Charles paleochannel. These sediments show weak or no internal reflections (fig. 3*F*). Small tributaries to the Cape Charles paleochannel are apparently filled with thicker Holocene sediments, which almost invariably contain biogenic gas, obscuring the seismic records (fig. 3*F*). Small, flat-lying remnants of older Pleistocene deposits may locally underlie the Holocene sediments on the marginal benches, but such deposits are difficult to distinguish from the underlying Tertiary strata. Most pre-Holocene deposits were apparently eroded from the interfluves and marginal benches during low sea-level stands and were preserved only in the deep paleochannels (Colman and Hobbs, 1987).

DISCUSSION

The reconstructed erosion surface at the base of the Cape Charles paleochannel is clearly of fluvial origin (fig. 4). The isopach map of the sediments, mostly of Holocene age, above this unconformity mirrors the pattern of the erosion surface, showing the close association between preexisting topography and sediment accumulation (fig. 5). In general, the thickest Holocene sediments occur in the paleochannels, whereas only thin sediments occur on the interfluves and marginal benches. Figures 4 to 9 were constructed assuming a sound velocity of 1,500 m/s for water and Holocene sediment, 1,600 m/s for the sediments that fill the Eastville channel system, and 1,800 m/s for the sediments that fill the Exmore channel system. The first velocity produces depths consistent with those derived from the limited number of cores in the study area and with more extensive core data farther south in the bay (Colman and Hobbs, 1987). The latter two velocities are largely guesses based on the greater age (and presumably consolidation) of the sediments that fill the Eastville and Exmore paleochannels, but they are consistent with the depths of these paleochannels as determined from boreholes on the Delmarva Peninsula (Mixon, 1985).

Biogenic gas is closely associated with the fill of the Cape Charles paleochannel system. The gas, presumably mostly methane produced by decomposition of organic matter, generally occurs within the upper 3 m of the section and commonly extends to the sea floor. The uppermost part of the gas-charged sediments reflects all the seismic energy, producing a characteristic seismic signature obscuring all strata below (figs. 3*A*, 3*D*, and 3*F-H*). Shallow cores taken in the gas-charged sediment show numerous bubbles and voids (J.P. Halka, unpub. data, 1987). The lateral transition between gas-charged and gas-free sediments in the seismic-reflection profiles is very abrupt and is most commonly associated with channel margins. No changes in lithology associated with this lateral transition are known from the seismic-reflection data or from limited core data, so that the transition appears to be related to sediment thickness. However, the presence of gas is presumably related to the organic matter and porosity of the sediments; farther south, where the channel-fill sediments are sandier and derived partly from outside the bay, biogenic gas is less common in the fill of the Cape Charles paleochannel (Colman and Hobbs, 1987). Gas-charged sediments are almost entirely restricted to channels of the Cape Charles system, and extend outside the channels only in areas such as some of the protected marginal embayments and small tributary estuaries. No gas has been observed in pre-Holocene sediments, suggesting that the production and trapping of the organic matter in the sediments and escape of the gas is completed over a period of several thousand to several tens of thousands of years. Because the base of the Cape Charles paleochannel is obscured by gas throughout the study area, a depth of 55 m was assumed for figures 4 and 5, which is consistent with its depth both to the north at the Kent Island Bridge and farther south (Colman and Hobbs, 1987, 1988). It is also consistent with the depths and low gradients of the older paleochannels in the study area.

In general, the bathymetry of the bay closely reflects the underlying Cape Charles erosion surface, indicating that, in large part, the present channels in the bay are simply partly filled remnants of the Cape Charles paleochannel. However, in the southern part of the study area, the modern channel in the main part of the bay is locally offset to the east of the Cape Charles paleochannel and is underlain by little or no Quaternary sediment. Off Smith Point, this relation suggests that Smith Point has prograded eastward, displacing the modern channel from its original position above the Cape Charles paleochannel (Colman and Hobbs, 1988). Off the mouth of the Potomac River, two bathymetric channels exist, one underlain by the main Cape Charles paleochannel and the present tributary channel of the Potomac River, and the other underlain only by the modern bathymetric channel of the main bay and relatively little channel fill sediments (fig. 3*G*). This relation and the presence of sandy sediments in the channel bottom suggests that the modern bathymetric channel of the main part of the bay has migrated eastward. In addition, Tertiary strata outcrop along the eastern margin of the Cape Charles paleochannel along much of its length between the Patuxent and Potomac Rivers (fig. 3*A*).

The erosion surface that marks the base of the Eastville paleochannel is less extensively preserved than that of the Cape Charles paleochannel (fig. 6), but it is not obscured by gas-charged sediments. Erosion during the formation of the Cape Charles erosion surface removed nearly all of the pre-existing Exmore sediment from the interfluves and parts of the Eastville channel system, especially in the northern part of the study area, where the trunk channel of the Cape Charles system directly overlies that of the Eastville system. However, most of the Eastville system can be reconstructed, and the fluvial origin of the erosion surface is clear.

The trunk channel of the Exmore paleochannel system is well preserved, but only a few of the major tributaries can be identified (fig. 7). As is the case for the Eastville system, most of the sediments of Exmore age on the interfluves was removed during subsequent low sea-level stands. The Exmore valley shows little regard for the present configuration of the bay, but instead follows the Honga River and Tangier Sound. Throughout this area and the area to the south (Colman and Hobbs, 1988), the Exmore paleochannel occurs only in areas east of the bay, eventually crossing beneath the Delmarva Peninsula (Mixon, 1985; Colman and Mixon, in press). This pattern suggests that the topographic high formed by Smith, South Marsh, and Bloodsworth islands and the islands west of the Honga River is older than the Exmore paleochannel. Conversely, the topography to the west must be younger. Part of Bloodsworth Island also must be younger than the Exmore paleochannel, because the channel passes through a gap in the topographic high beneath the island.

Figures 8 and 9 show the depth to Tertiary strata and the total thickness of Quaternary deposits, respectively, in the study area and demonstrate the net effect of Quaternary sea-level cycles. The top of the Tertiary is a composite erosion surface that retains the strong fluvial character resulting from several cycles of channel incision. The thickness of the total Quaternary sedimentary section also shows the effect of preexisting fluvial topography on the deposition and preservation of the sediments.

Reconstructions of the three paleochannel systems are shown in figure 10, in which the channel margins were defined by the 30-meter depth contour to each of the fluvial unconformities (figs. 4, 6, and 7). All three paleochannels continue to the south in the bay, ultimately crossing beneath the southern Delmarva Peninsula (Colman and Hobbs, 1987, 1988). The three paleochannel systems contrast considerably in their configurations. Each younger channel system is located progressively farther west, although the Cape Charles paleochannel overlies the Eastville paleochannel in the northern part of the study area. Tangier Sound is the location of the trunk channel of Exmore age, a tributary of Eastville age that heads in the Honga River and crosses through Kedges Straights to the main part of the bay, and a tributary channel of Cape Charles age that follows the length of the Sound.

Three generations of each of major tributaries on the west side of the bay, the Potomac and the Patuxent Rivers, have been identified. The three generations of the Potomac River are close to one another in the main part of the bay and converge near the present mouth of the river (fig. 3*H*). This may explain why Knebel and others (1981) were only able to identify one age of channel within the present tributary estuary. The three generations of the Patuxent River are widely spaced, such that the older channels are found progressively farther south. The oldest of the Patuxent channels, that of Exmore age, appears to have flowed nearly due south into the Potomac.

The geologic map of the study area (fig. 11), constructed by excluding the upper 5 m of Holocene sediment, reflects the complexity produced by the intersection of the paleochannel systems of different ages.

GEOLOGIC HISTORY

The Chesapeake Bay area has alternated between fluvial and estuarine modes repeatedly during Quaternary time. In the study area, these modes are reflected in the erosion of the three paleochannels by the Susquehanna River system during falling sea levels that accompanied continental glaciations and in the filling of the channels with estuarine sediments during sea-level transgressions that accompanied major deglaciations (Colman and Mixon, in press). Age information derived from uranium-series and amino acid analyses for the two older paleochannels, the Exmore and the Eastville, is sparse and somewhat equivocal, especially for the Exmore paleochannel. Most of the age information comes from high-sea-level deposits that overlie the estuarine channel fills beneath the Delmarva Peninsula (Mixon and others, 1982; Mixon, 1985; Szabo, 1985; Colman and Mixon, in press; Wehmiller and others, in press).

The uppermost deposits of the transgression that filled the Exmore paleochannel appear to be at least 200 ka (Mixon and others, 1982) and may be considerably older (Colman and Mixon, in press). The paleochannel itself was probably eroded during the glacial sea-level lowstand that immediately preceded deposition of the channel-fill deposits (Colman and Mixon, in press). The Eastville paleochannel was filled during the last major interglacial (Sangamon) transgression (Mixon, 1985), which culminated about 125 ka (Colman and Mixon, in press), although uranium-series age estimates range to as young as 70 ka for the youngest of the transgressive deposits (Mixon and others, 1982; Szabo, 1985). The Cape Charles paleochannel was clearly carved during the last (Wisconsinan) glaciation, about 18 ka, when sea level fell to about -85 m on the Atlantic continental shelf (Dillion and Oldale, 1978). Radiocarbon dates on sediments from the lower part of the channel fill range from about 8 to 15 ka (Harrison and others, 1965; Meisburger, 1972; Colman and Hobbs, 1987). The Cape Charles paleochannel has been only partially filled by the continuing Holocene transgression.

The three paleochannel systems form an age sequence that is progressively older and less related to the current configuration of the bay to the northeast (fig. 10). These trends, which are due to changes in geomorphology that occurred during periods of interglacial high sea level, include (1) filling of the paleochannels by estuarine sediments, and (2) southward migration of the bay mouth due to building of barrier-spits and southward progradation of the southern Delmarva Peninsula (Mixon, 1985; Colman and Hobbs, 1987; Colman and Mixon, in press). During the present interglaciation, the axial channel of the bay at its mouth has migrated southwestward by as much as 12 km due to these processes (Colman and Hobbs, 1987). As a result, the incision of each successive paleochannel occurred farther to the southwest.

Of the three major marine transgressions that are recorded in the study area, the history and paleogeography of the Holocene transgression, which is continuing at present, is best known because of the preservation of the underlying Cape Charles fluvial erosion surface (fig. 4). This surface is preserved inside the present bay mouth because transgressive erosion was minimal due to the sheltered conditions that existed in the restricted river estuaries. At the height of the last glaciation, about 18 ka, world-wide sea level was 120±60 m lower than at present (Bloom, 1983a); Dillon and Oldale (1978) have estimated that sea level stood at about -85 m on the mid-Atlantic shelf. At that time, the shoreline was many kilometers east of the present Delmarva Peninsula and an integrated fluvial drainage system occupied the Chesapeake Bay. Deep incision of the channels of this system into the underlying Tertiary and younger deposits occurred. Except where they were preserved in the deep older paleochannels, most Pleistocene deposits on the valley walls and interfluves were removed by erosion. Concurrently, the basal channel-fill deposits, consisting of coarse fluvial sand and gravel, were deposited in the Cape Charles channel bottoms.

As sea level rose following the last glaciation, the fluvial channels began to fill with the relatively fine-grained sediment that comprises the bulk of the channel-fill deposits (Mixon, 1985; Colman and Mixon, in press). The initial part of this filling was probably dominated by fluvial sediment, deposited in response to the rising base level. As the valleys were submerged, creating narrow river estuaries, complex associations of sand, mud, and peat were deposited. Near the bay mouth, these sediments have yielded radiocarbon dates of between about 15 and 8 ka (Harrison and others, 1965; Meisburger, 1972).

The interfluves began to submerge when sea level reached about -20 m, and they were almost completely covered by the time sea level reached -10 m (fig. 4). When sea level was at -5 m, the bay would have been somewhat smaller than at present, but it would have been in essentially its modern configuration. Although considerable variation in local sea-level curves exists (Bloom, 1983b), three curves based on data from near the Chesapeake Bay (Newman and Rusnak, 1965; Ellison and Nichols, 1976; Belknap and Kraft, 1977) suggest that local sea level reached -10 m between 5 and 6 ka and that local sea level was within a few meters of its present position by 3 ka.

Chesapeake Bay is a partially mixed estuary that has a turbidity and depositional maximum associated with the net nontidal circulation pattern (Meade, 1969; Schubel, 1968, 1972). Significant sediment accumulation probably accompanied the migration of the depositional maximum up the river-estuary system to its present position north of the study area during the Holocene sea-level rise. However, it seems likely that much of the deposition of the estuarine fill occurred after sea level had overtopped the interfluves and a more open bay existed. The seismic-reflection structure of the deposits farther south, where they are not obscured by biogenic gas, supports this conclusion (Colman and Hobbs, 1987). The present bathymetry of the study area and variations in the degree to which the Cape Charles paleochannel is filled suggest that although modern deposition is concentrated in the deeper channels, actual depositional patterns are complex.

ACKNOWLEDGMENTS

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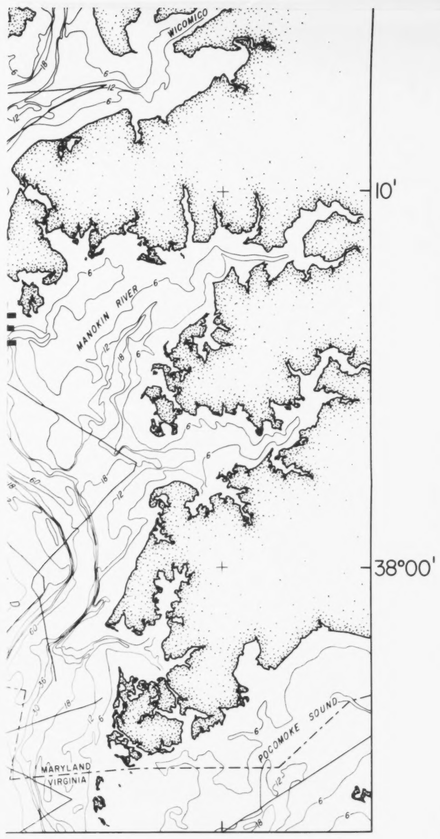

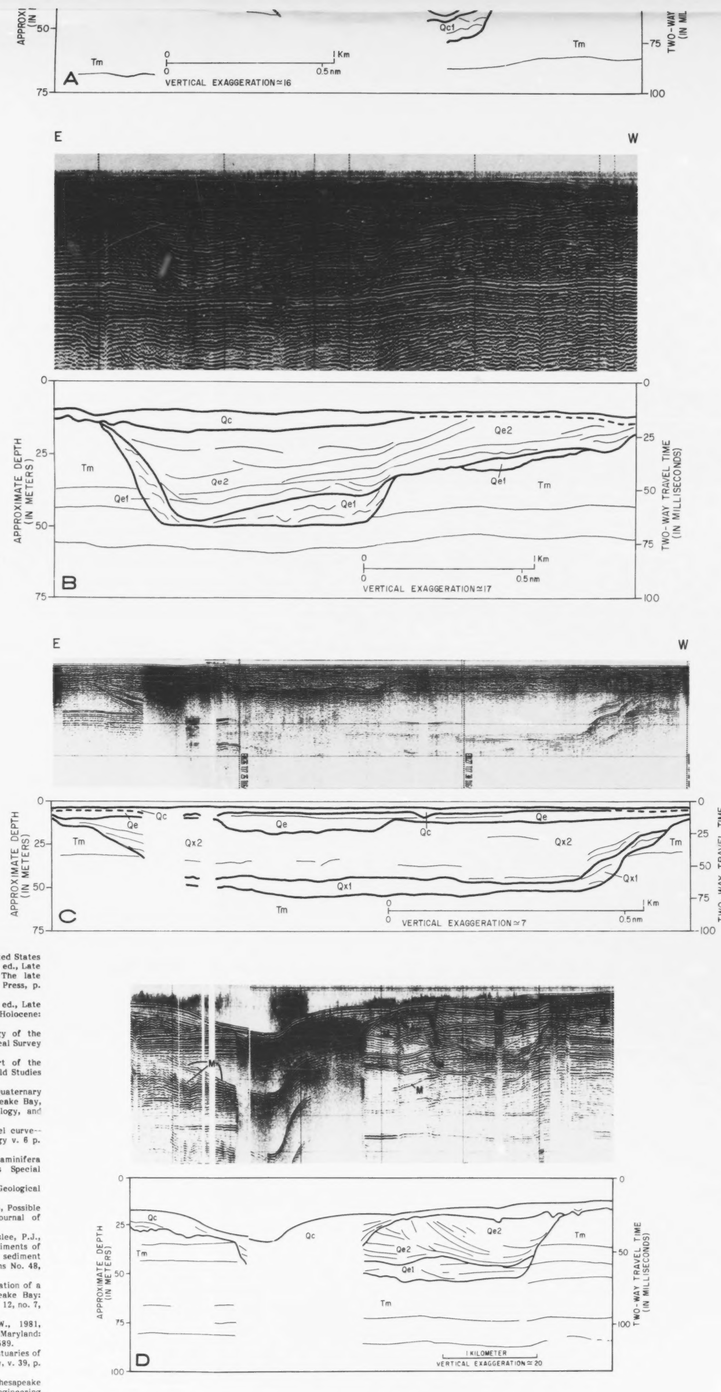

Figure 3.--Selected seismic-reflection profiles. See figure 2 for locations, table 1 for correlation of stratigraphic units, and the Stratigraphy section in the text for interpretation and description of units. Depth scale on seismic profiles assumes a sound velocity of 1,500 m/s in water and Quaternary sediments. M, multiple reflection; G, gas-charged sediments.

MAPS SHOWING QUATERNARY GEOLOGY OF THE SOUTHERN MARYLAND PART OF THE CHESAPEAKE BAY

By
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and
Jeffrey P. Halka, Maryland Geological Survey
1989

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The use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey or the Maryland Geological Survey

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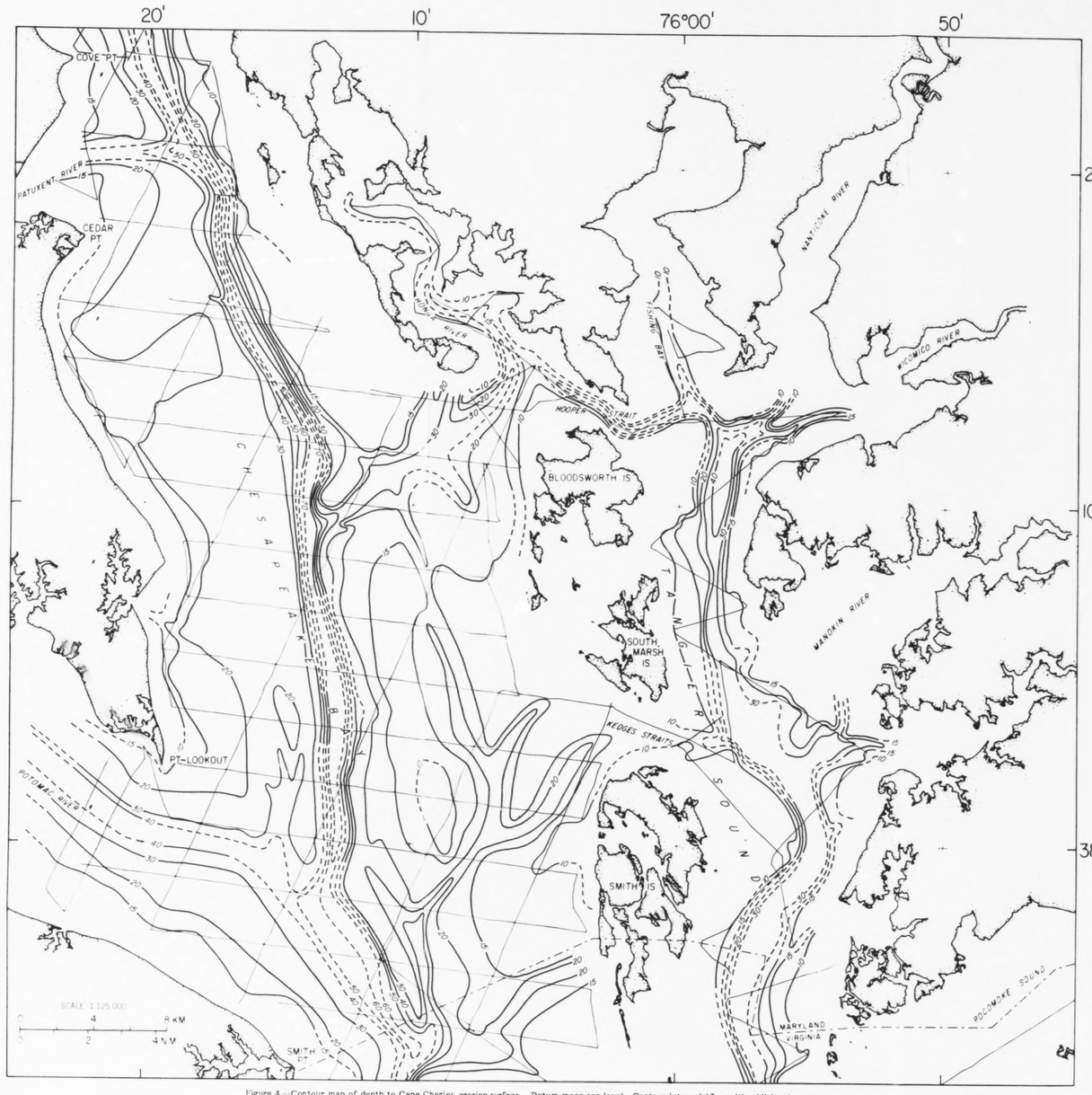

Figure 4.--Contour map of depth to Cape Charles erosion surface. Datum mean sea level. Contour interval 10 m with additional contour at 15 m. Contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and sediments above the erosion surface assumed (see text).

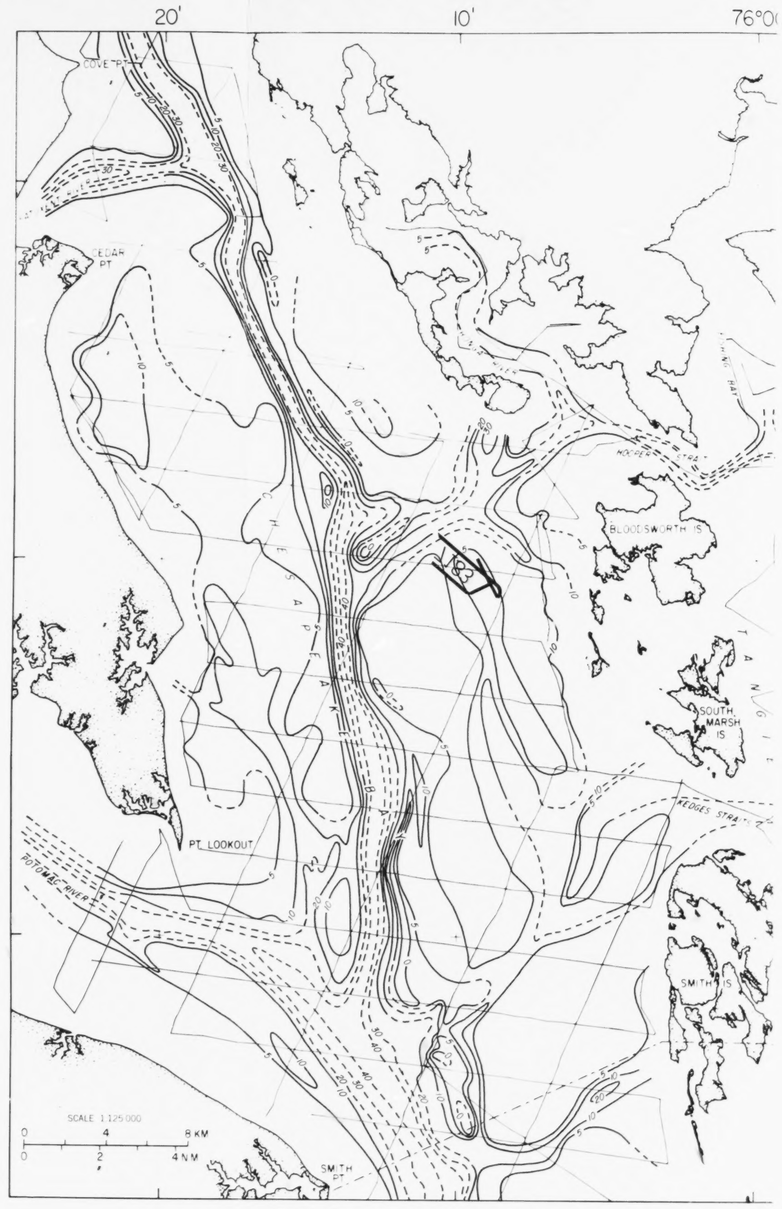

Figure 5.--Isopach map of sediments above the Cape Charles erosion surface (upper Pleistocene and Ho with additional contour at 5 m; contours dashed where inferred or uncertain. Sound velocity of 1,5 m/s in Quaternary sediments assumed (see text).

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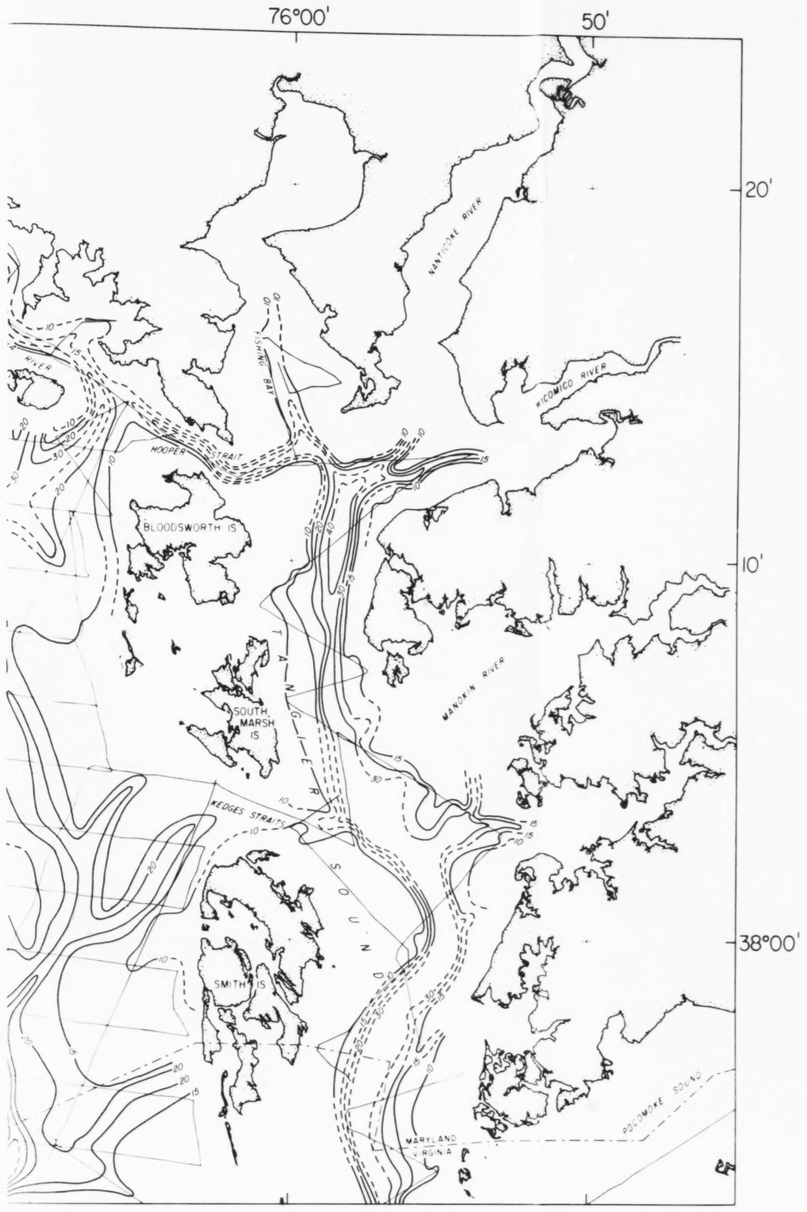

erosion surface. Datum mean sea level. Contour interval 10 m with additional contour ...ed or uncertain. Sound velocity of 1,500 m/s in water and sediments above the erosion

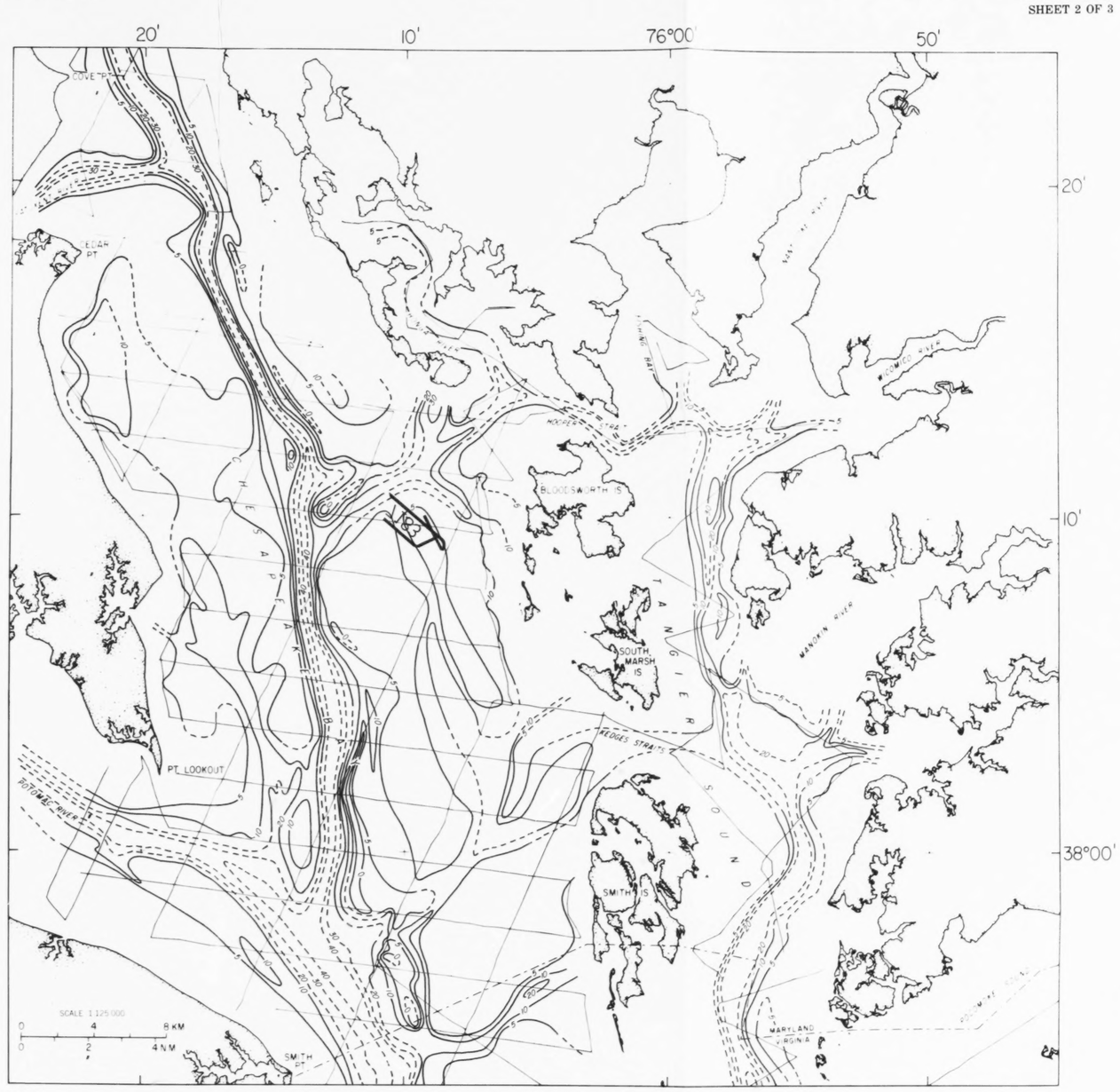

Figure 5.--Isopach map of sediments above the Cape Charles erosion surface (upper Pleistocene and Holocene). Contour interval 10 m with additional contour at 5 m; contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and 1,500-1,800 m/s in Quaternary sediments assumed (see text).

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Figure 4.--Contour map of depth to Cape Charles erosion surface. Datum mean sea level. Contour interval 10 m with additional contour at 15 m. Contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and sediments above the erosion surface assumed (see text).

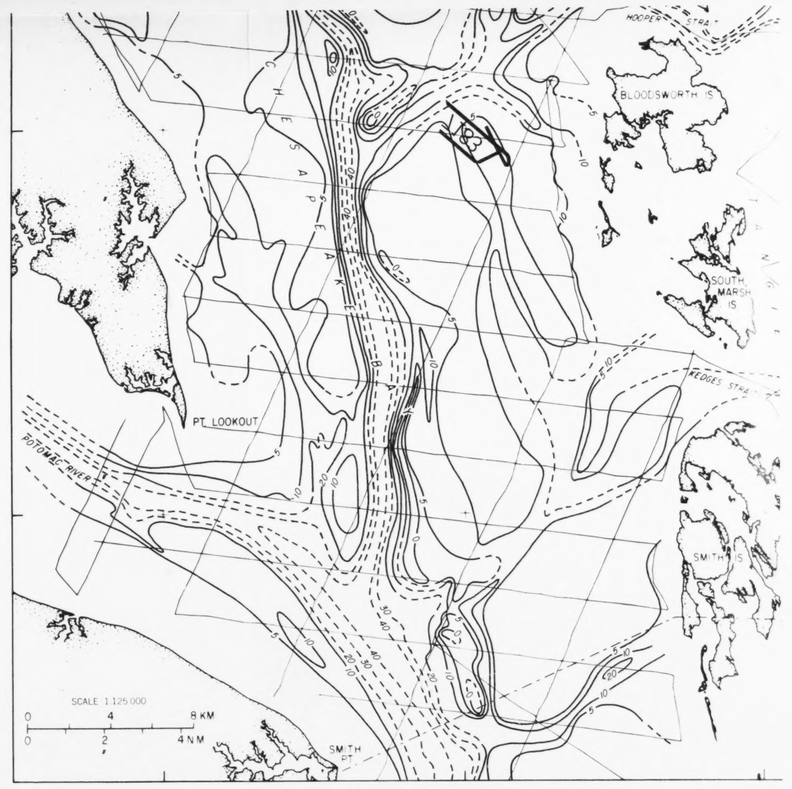

Figure 5.--Isopach map of sediments above the Cape Charles erosion surface (upper Pleistocene and Ho with additional contour at 5 m; contours dashed where inferred or uncertain. Sound velocity of 1,5 m/s in Quaternary sediments assumed (see text).

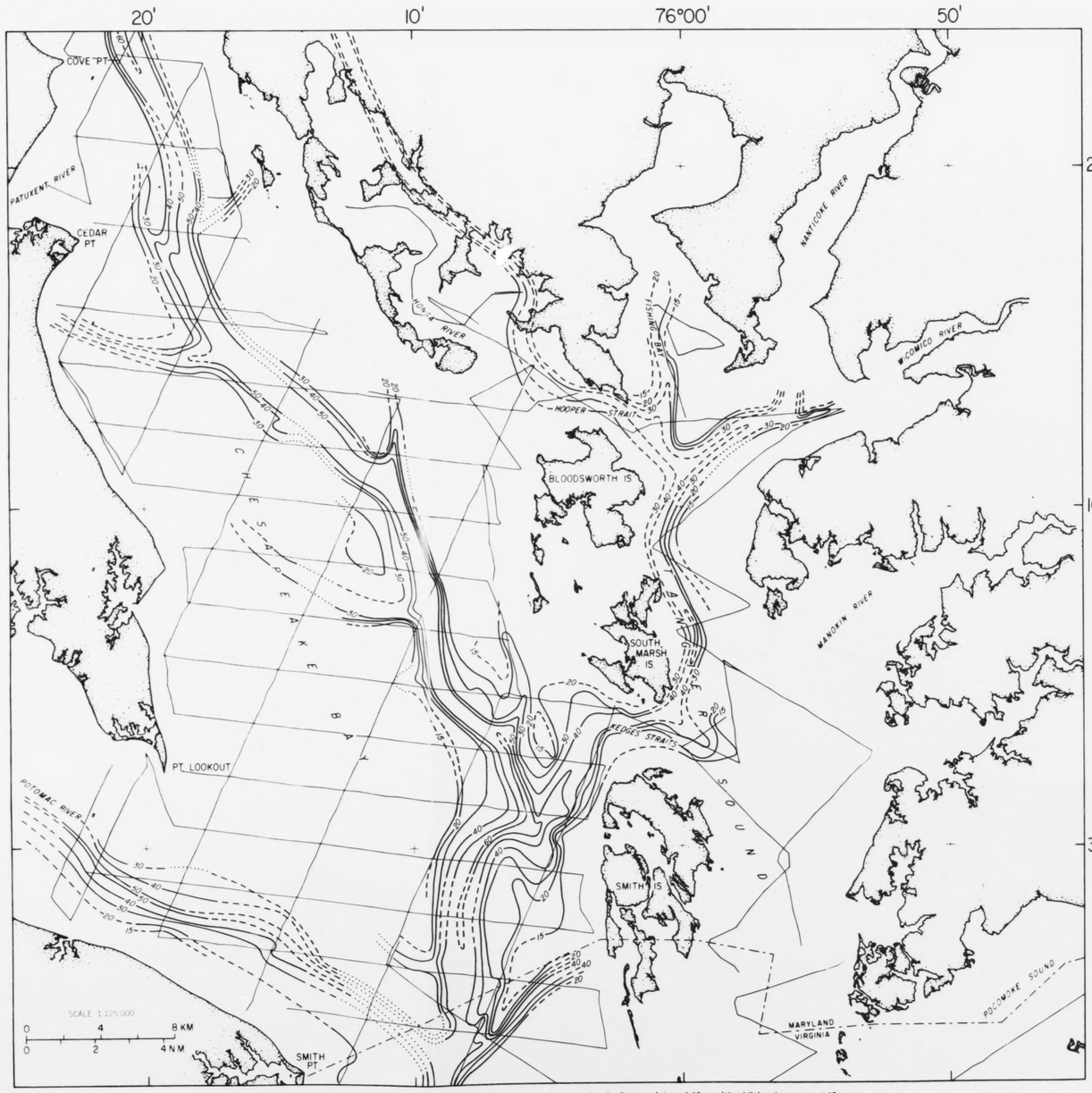

Figure 6.--Contour map of depth to Eastville erosion surface. Datum mean sea level. Contour interval 10 m with additional contour at 15 m; contours dashed where inferred or uncertain, dotted where surface eroded by younger channel. Sound velocity of 1,500 m/s in water and 1,500-1,600 m/s in sediments above the erosion surface assumed (see text).

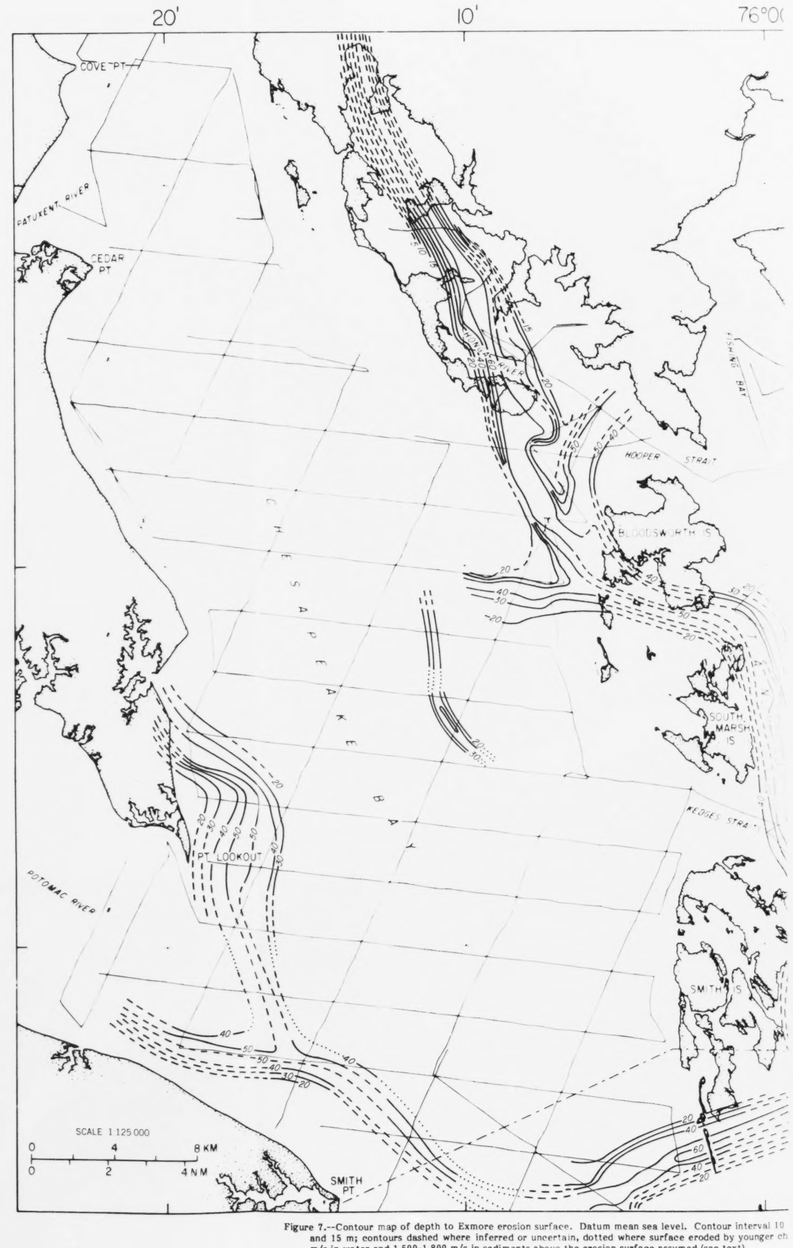

Figure 7.--Contour map of depth to Exmore erosion surface. Datum mean sea level. Contour interval 10 and 15 m; contours dashed where inferred or uncertain, dotted where surface eroded by younger ch m/s in water and 1,500-1,800 m/s in sediments above the erosion surface assumed (see text).

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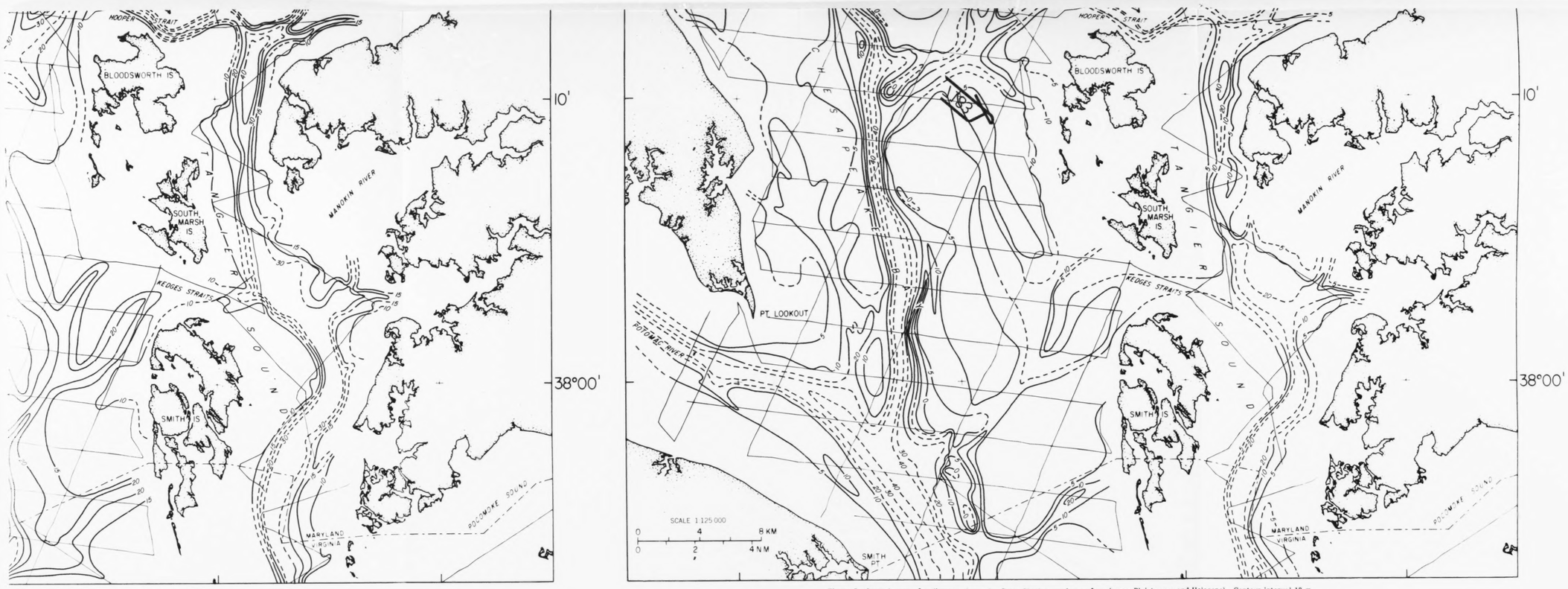
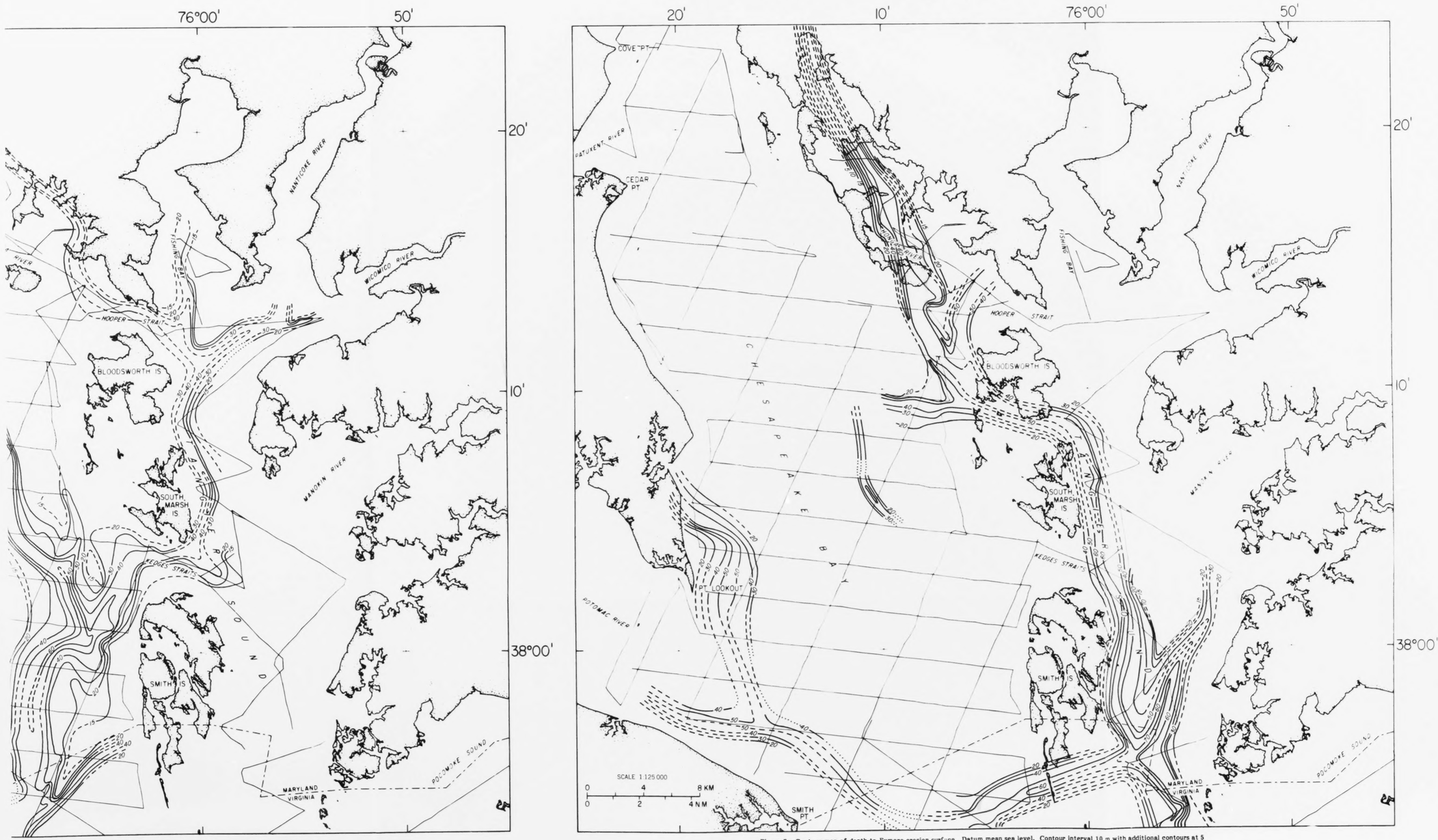


harles erosion surface. Datum mean sea level. Contour interval 10 m with additional contour at 5 m ferred or uncertain. Sound velocity of 1,500 m/s in water and sediments above the erosion

Figure 5.—Isopach map of sediments above the Cape Charles erosion surface (upper Pleistocene and Holocene). Contour interval 10 m with additional contour at 5 m; contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and 1,500-1,800 m/s in Quaternary sediments assumed (see text).



ie erosion surface. Datum mean sea level. Contour interval 10 m with additional contour at 15 r uncertain, dotted where surface eroded by younger channel. Sound velocity of 1,500 m/s in ts above the erosion surface assumed (see text).

Figure 7.—Contour map of depth to Exmore erosion surface. Datum mean sea level. Contour interval 10 m with additional contours at 5 and 15 m; contours dashed where inferred or uncertain, dotted where surface eroded by younger channel. Sound velocity of 1,500 m/s in water and 1,500-1,800 m/s in sediments above the erosion surface assumed (see text).

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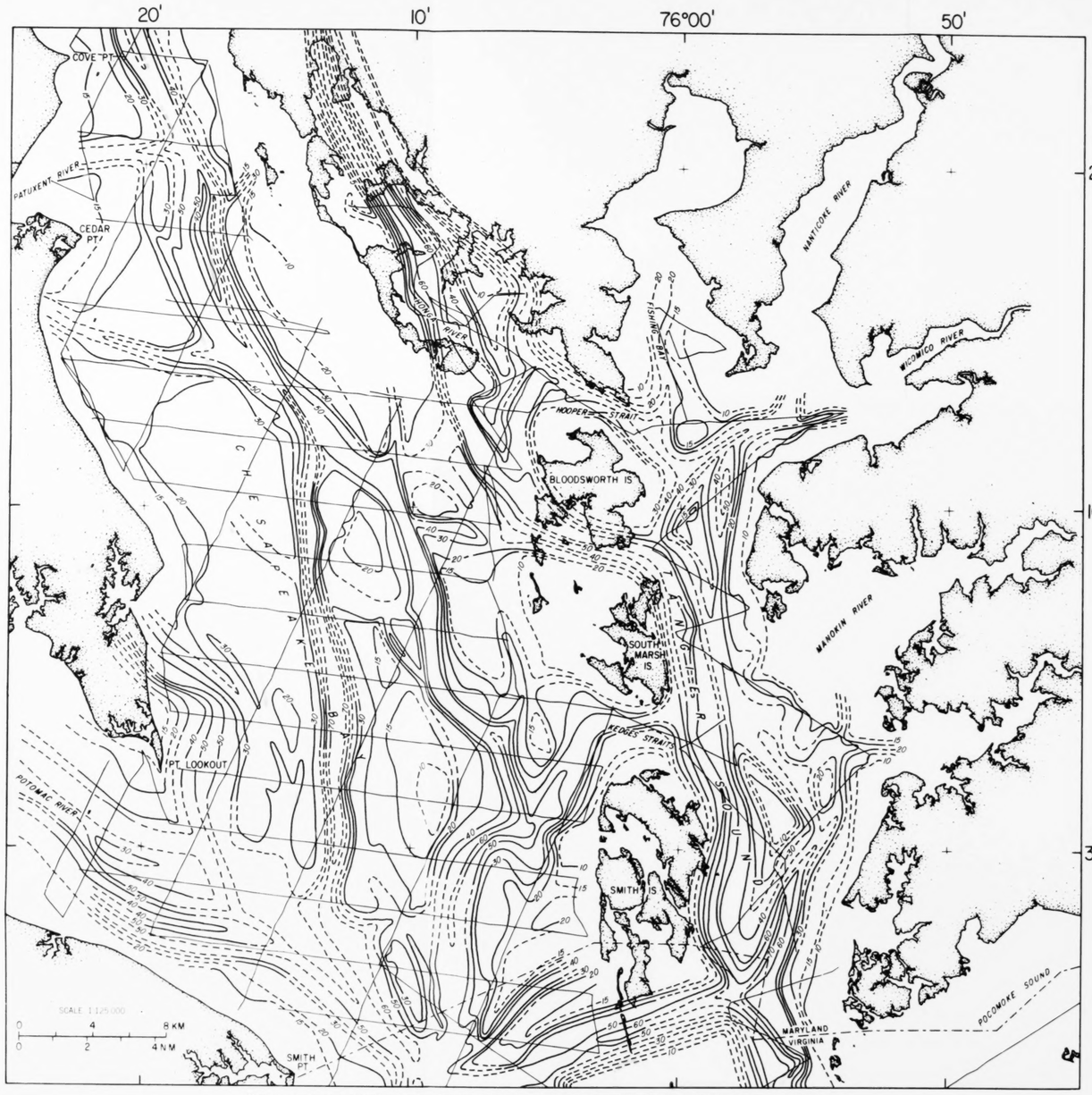


Figure 8.--Contour map of depth to Tertiary deposits. Datum mean sea level. Contour interval 10 m with additional contours at 5 and 15 m; contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and 1,500-1,800 m/s in Quaternary sediments assumed (see text).

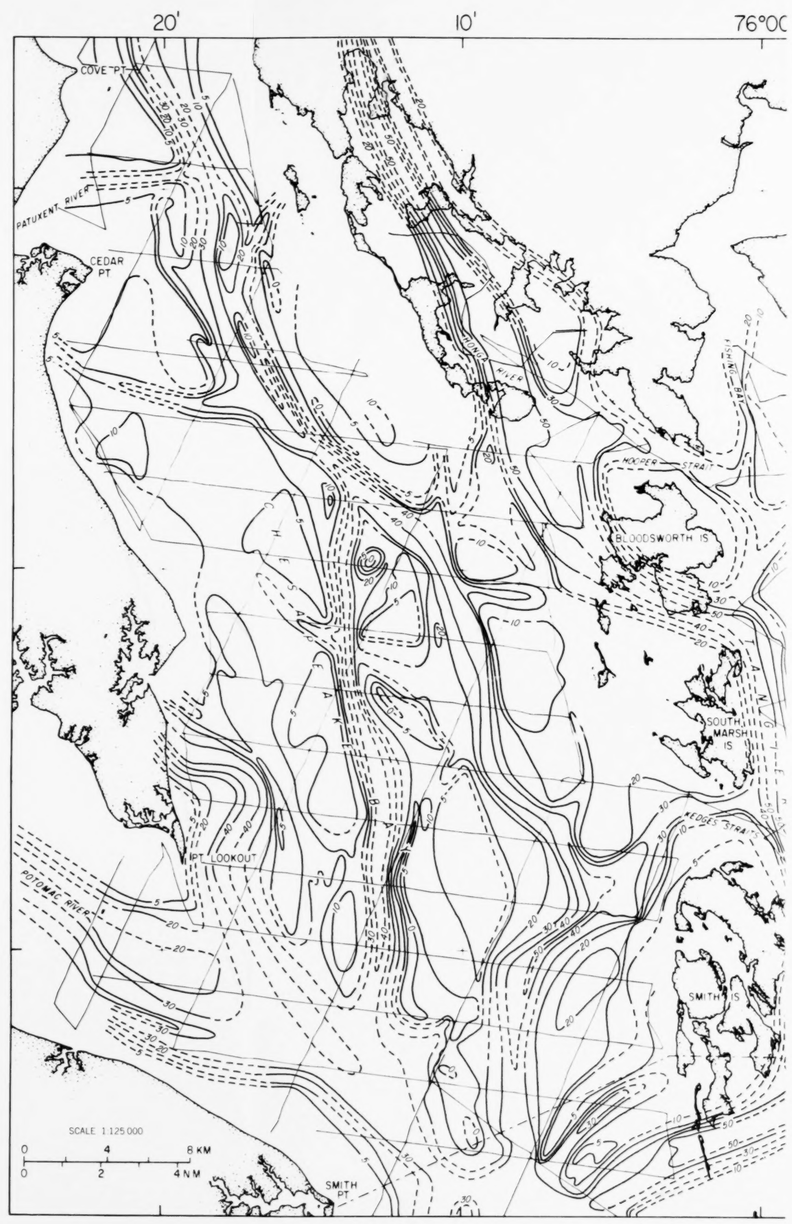
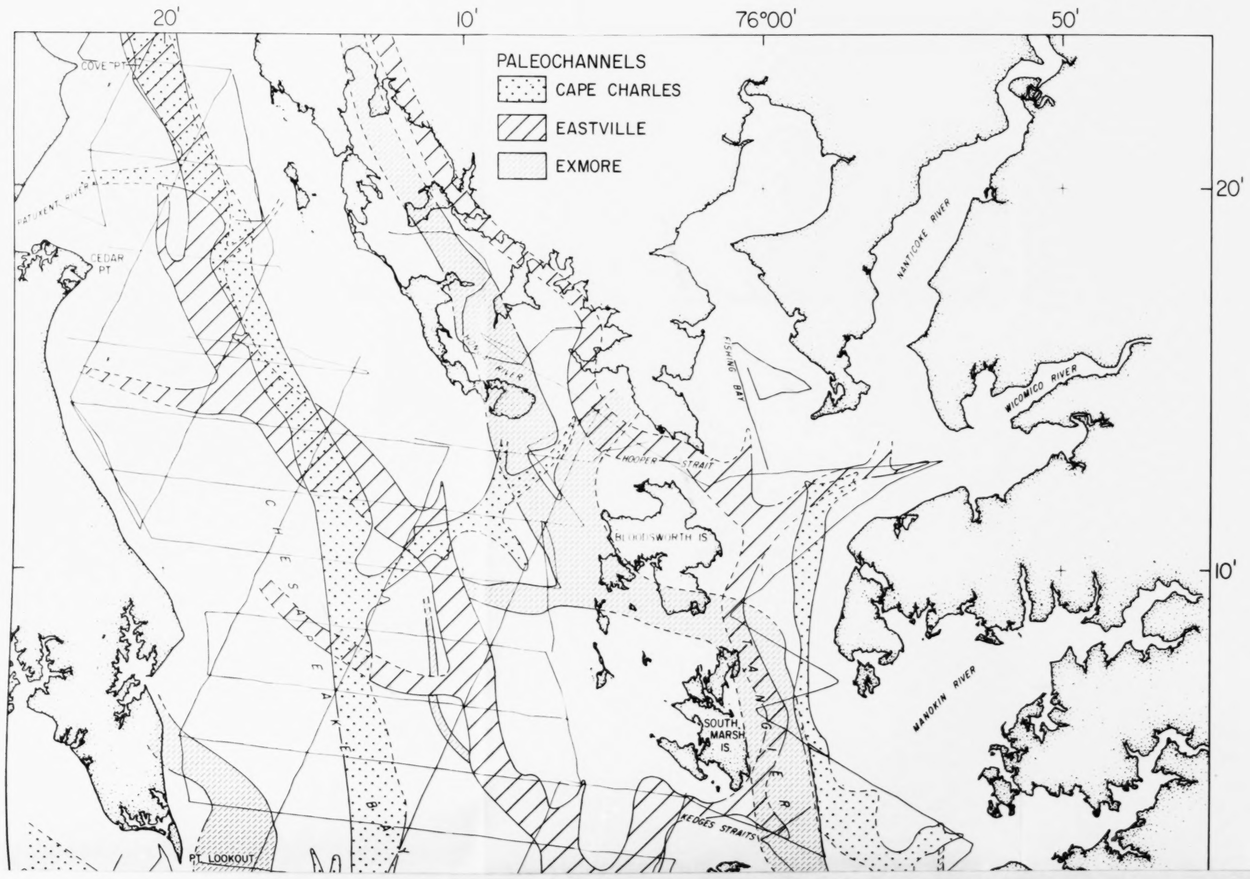
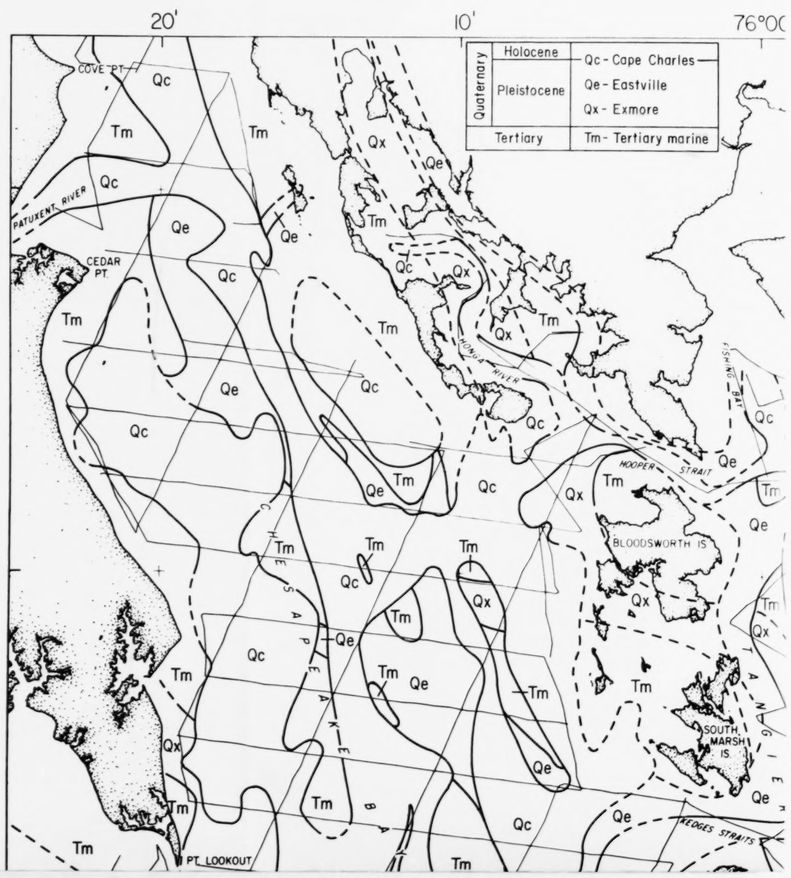


Figure 9.--Isopach map of Quaternary sediments. Contour interval 10 m with additional contour at 5 m; or uncertain. Sound velocity of 1,500 m/s in water and 1,500-1,800 m/s in Quaternary sediments assu





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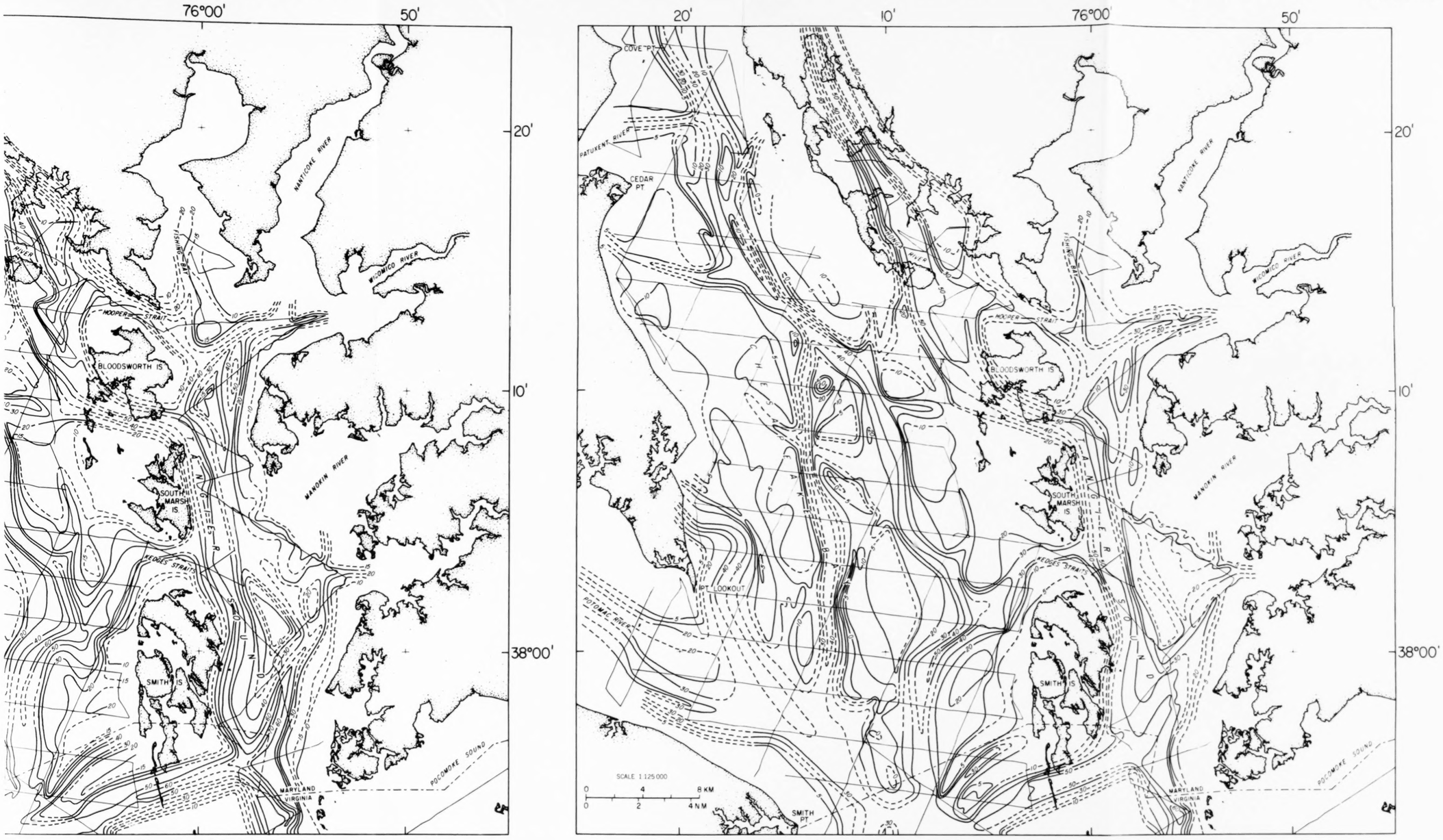

Deposits. Datum mean sea level. Contour interval 10 m with additional contours at 5 and 15 m; contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and 1,500–1,800 m/s in Quaternary sediments

Figure 9.--Isopach map of Quaternary sediments. Contour interval 10 m with additional contour at 5 m; contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and 1,500–1,800 m/s in Quaternary sediments assumed (see text).

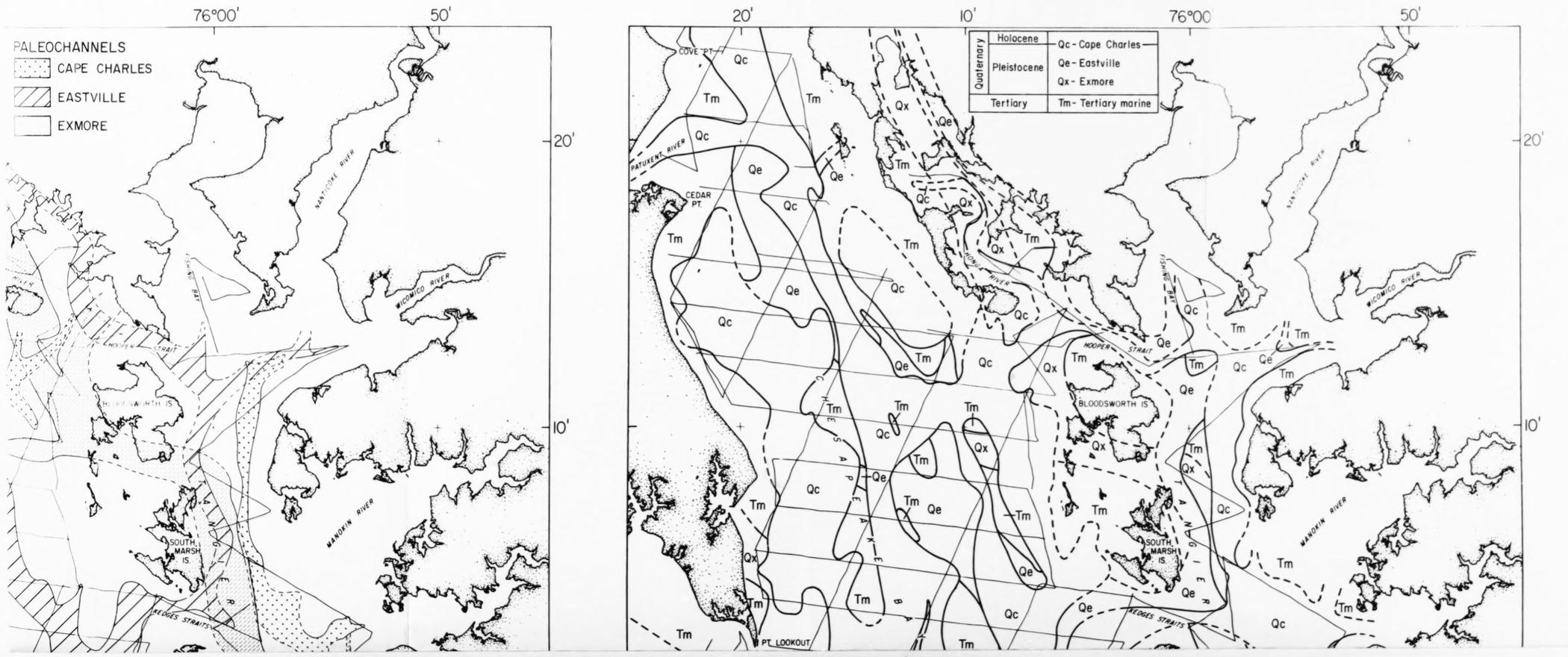

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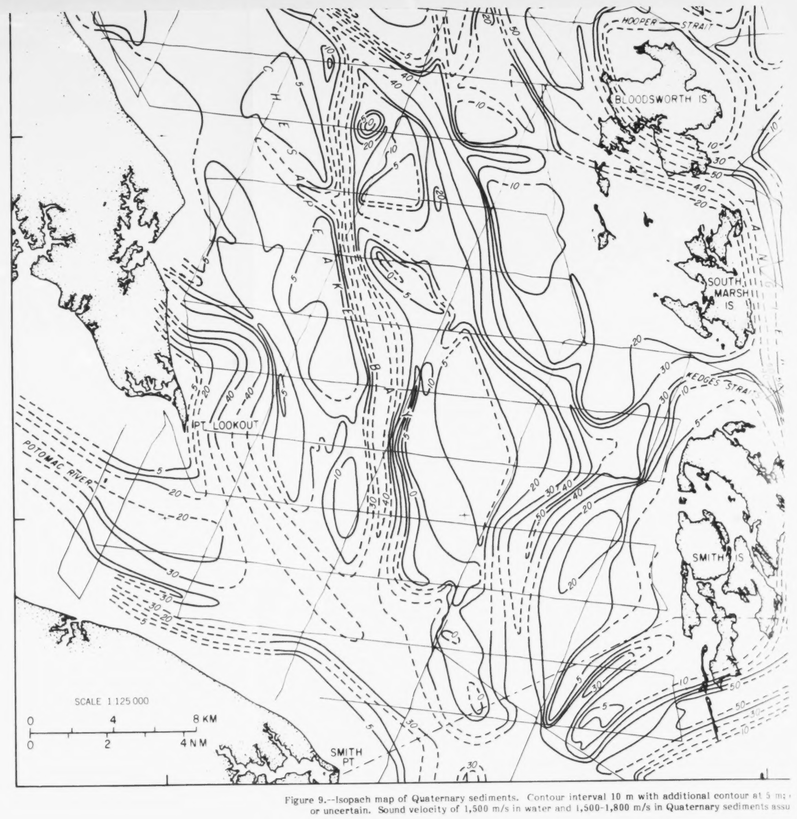
Figure 8.--Contour map of depth to Tertiary deposits. Datum mean sea level. Contour interval 10 m with additional contours at 5 and 15 m; contours dashed where inferred or uncertain. Sound velocity of 1,500 m/s in water and 1,500-1,800 m/s in Quaternary sediments assumed (see text).



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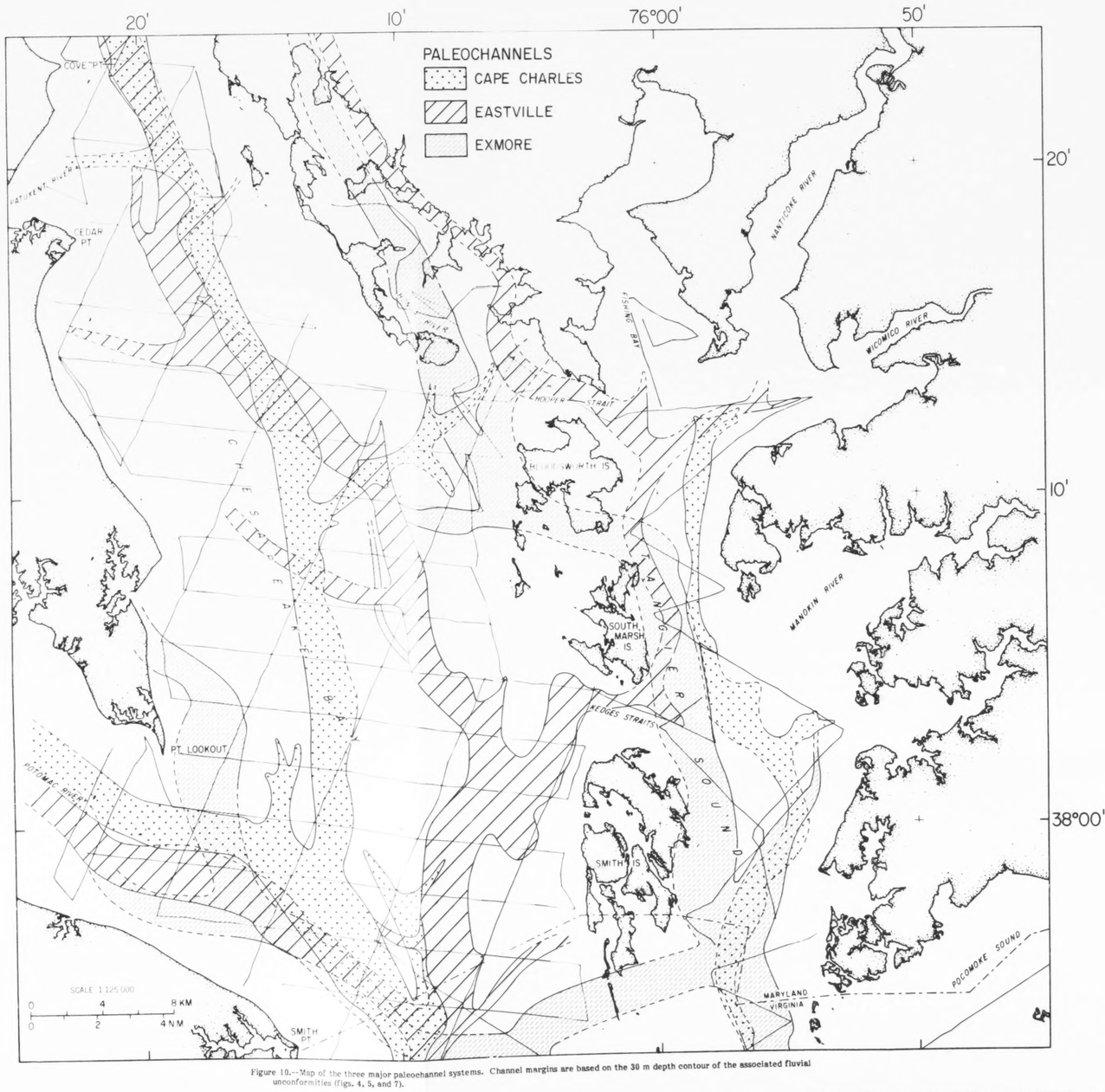

Figure 10.--Map of the three major paleochannel systems. Channel margins are based on the 30 m depth contour of the associated fluvial unconformities (figs. 4, 5, and 7).

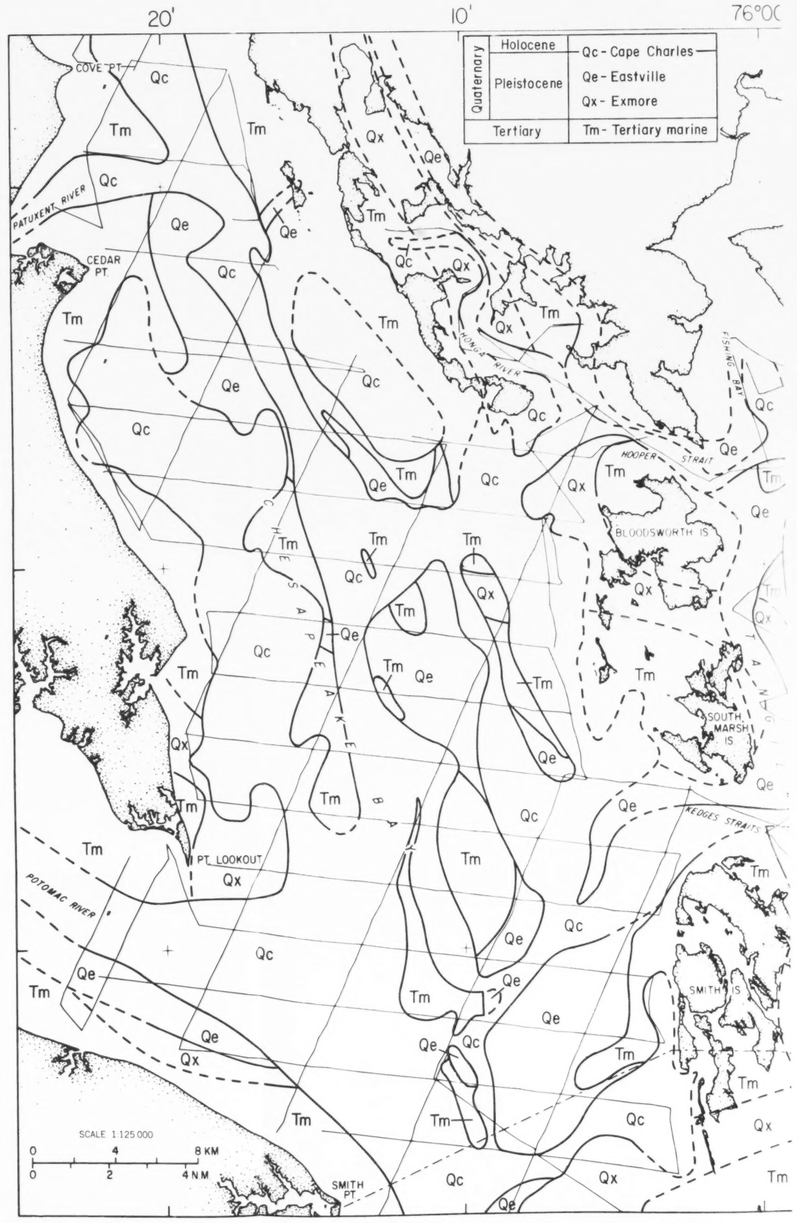

Figure 11.--Geologic map of the study area excluding the upper 5 m of Holocene sediment. See Str
description of map units and Table 1 for their correlation.

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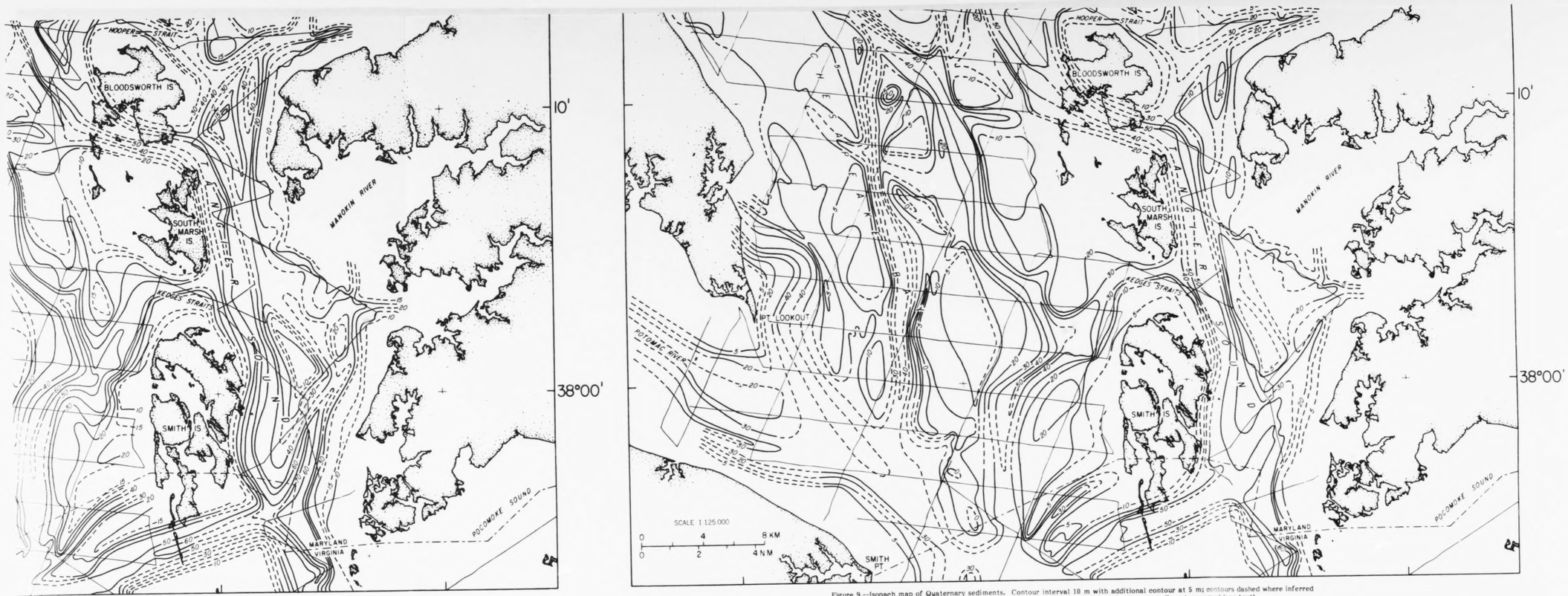

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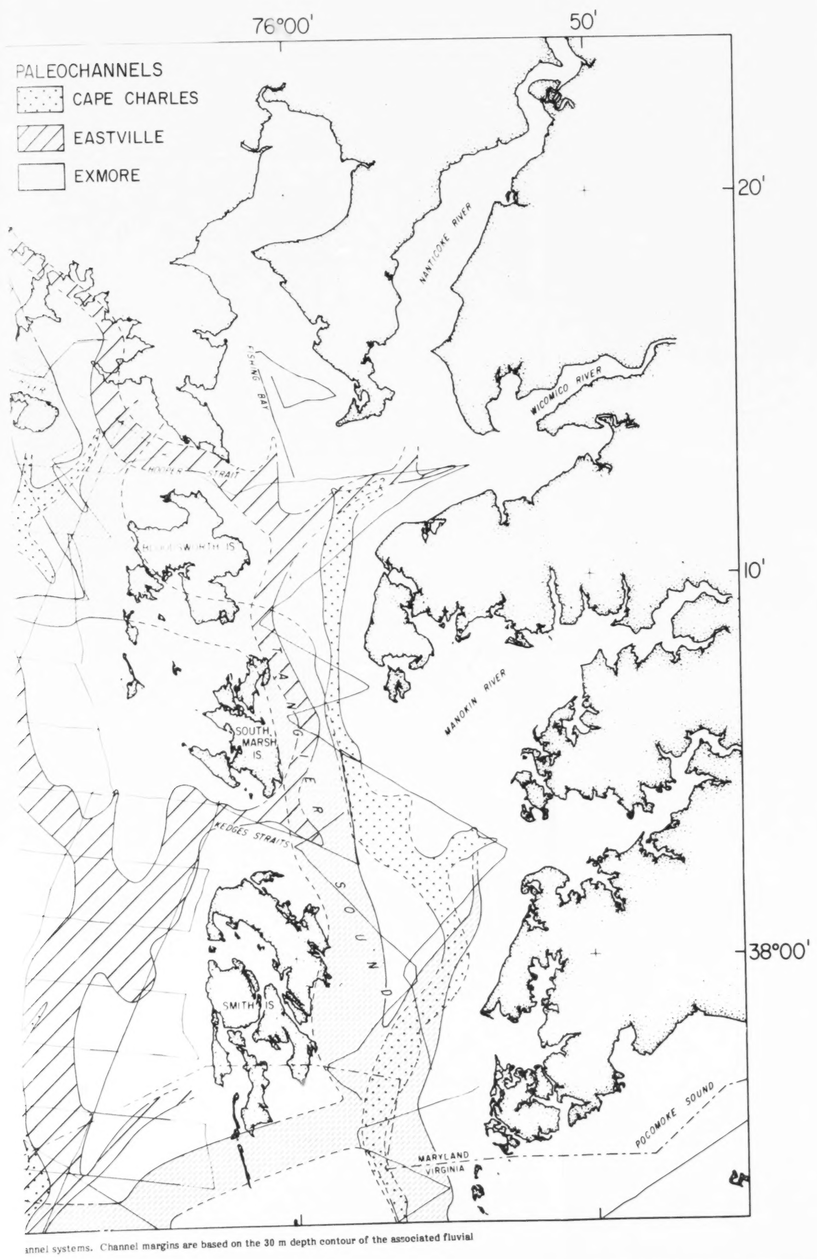
...bottom. Datum mean sea level. Contour interval 10 m with additional contours at 5 and 15 ...certain. Sound velocity of 1,500 m/s in water and 1,500-1,800 m/s in Quaternary sediments



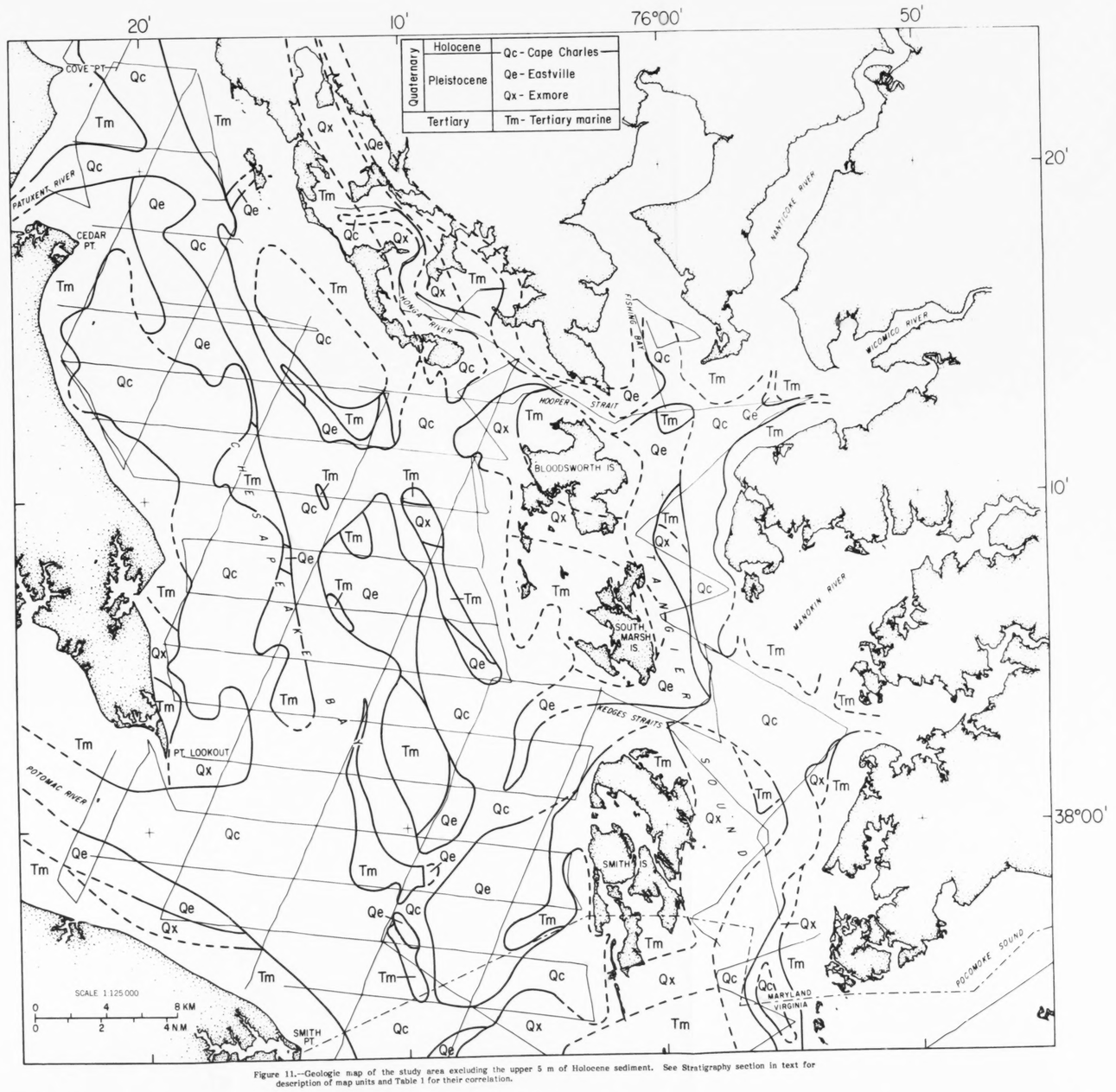


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Figure 11.--Geologic map of the study area excluding the upper 5 m of Holocene sediment. See Stratigraphy section in text for description of map units and Table 1 for their correlation.

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